Digitized by Google

15. 8642

Digitized by Google

Digitized by Google

Digitized by Google

THE USEFUL

ARTS AND MANUFACTURES

OF

GREAT BRITAIN.

Second Series,

METALS, CHEMICAL MANUFACTURES, &c.

BY CHARLES TOMLINSON,

LECTURER ON SCIENCE, KING'S COLLEGE SCHOOL, LONDON.

PUBLISHED UNDER THE DIRECTION OF
THE COMMITTEE OF GENERAL LITERATURE AND EDUCATION,
APPOINTED BY THE SOCIETY FOR PROMOTING
CHRISTIAN KNOWLEDGE.

LONDON:
SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE;
SOLD AT THE DEPOSITORIES:
77, GREAT QUEEN STREET, LINCOLN'S INN FIELDS;
4, ROYAL EXCHANGE; 16, HANOVER STREET, HANOVER SQUARE;
AND BY ALL BOOKSELLERS.

*** *The Treatises in this Volume were originally published in a separate form, and many of them have been more than once reprinted: in such cases the Statistics have been brought down to the present time; but in those Treatises which have not been reprinted, the Statistics belong to the date of their original publication.*

CONTENTS OF THE SECOND SERIES.

MANUFACTURE OF IRON.

Introduction, page 3—Historical Notices of Iron, 4—Distribution of Iron Ores; Mining Operations, 24—Theory of Smelting, 30—Roasting the Ore, 32—Coking the Coal, 33—Smelting, 35—The Hot Blast, 48—Refining, 54—Puddling, 57—Shingling, 59—Rolling, 60—Varieties of Manufactured Iron, 67—Statistics of the Iron Manufacture, 69.

STEEL, AND MANUFACTURES IN IRON AND STEEL.

The Manufacture of Steel, page 1—Tilting, 6—Cast Steel, 10—Manufactures in Iron and Steel: The Foundry, 17—Planing Iron, 29—Manufacture of Nails and Screws, 35—Manufacture of Gun-Barrels, 54—Wire Drawing, 64.

MANUFACTURES IN IRON AND STEEL—*concluded.*

The Manufacture of Needles, 1—Manufacture of Files, 19—Saws, 30—Manufacture of Cutlery, 41—Railway Carriage Springs, 62.

COPPER, TIN, LEAD, AND ZINC.

Introductory Remarks, page 1—Historical Notice of Copper, 6—Historical Notice of Tin, 12—Historical Notice of Lead, 22—Mining, 32.

COPPER, TIN, LEAD, AND ZINC—*concluded.*

Dressing the Ores, 1—Smelting the Ores, 12—Manufacture of Brass, 27.

BUTTONS, PINS, TIN PLATE, SHOT, &c.

Manufacture of Buttons, page 32—Manufacture of Pins, 43—Manufacture of Tin-Plate, 50—Manufacture of Shot and Lead Pipes, 54.

POTTERY, PORCELAIN, AND ENCAUSTIC TILES.

Historical Notices of Pottery, Stoneware, Porcelain, and Encaustic Tiles, page 1—Varieties of Ceramic Ware, 19—Materials of Earthenware, 21—Mixing the Materials, 29—Throwing, 34—Turning, 37—Pressing, 40—Casting, 44—Baking the Biscuit Ware, 45—Glazing Biscuit Ware, 50—Printing on Biscuit Ware, 53—Painting and Ornamenting the Ware, 56—The Manufacture of Encaustic Tiles, 62—Statistics, 66.

Digitized by Google

GLASS.

Historical Notice, page 3—Materials of the Manufacture, 8—Preparation of the Materials: The Furnaces and Glass-Pots, 11—Manufacture of Articles in Flint Glass, 19—Manufacture of Crown-Glass, 25—Manufacture of Plate-Glass, 28—Statistics, 32.

LEATHER, PARCHMENT, AND GLUE.

Introduction, page 3—Varieties of Skins used in Tanning, 4—Vegetable Substances used in Tanning, 8—Preparation of Thick Leather, 10—Currying, 17—Preparation of Thin Leather, 21—Tanning with Sumach, 23—Tawing, 27—Dressing in Oil, 30—Statistics of Leather, 31—The Manufacture of Parchment, 33—The Manufacture of Glue, 43.

SUGAR.

Historical Notice of the Sugar-Cane, page 3—Varieties and Sources of Sugar, 6—The Manufacture of Sugar in the West Indies, 9—Manufacture of Sugar in the East Indies, 18—Beet-Root Sugar, 19—Maple Sugar, 22—Sugar Refining, 23—Sugar-Candy, 38—Statistics of Sugar, 38.

SULPHURIC ACID, SODA, AND SOAP.

Historical Notice of Sulphuric Acid, page 1—Sulphur, 8—Sulphurous and Sulphuric Acids, 14—The Manufacture of Soda, 27—The Manufacture of Soap, 38.

COALS, AND THE MANUFACTURE OF GAS.

Coals and the Collieries, page 1—The Manufacture of Gas, 25—Historical Notice, 25—Nature of the Gas, 28—The Retorts, 29—Products of Distillation, 32—The Condensers, 36—The Purifiers, 38—The Scrubber, 42—The Gasometers, 42—The Governor, 48—The Gas-meter, 50—Flame, 52—A Candle, 53—Gas-burners, 55.

ILLUSTRATIONS

IN THE SECOND SERIES.

IRON.

PAGE
1. The Forge (*Colebrook Dale*) . . . 2
2, 3. Sparry Iron Ore and Hæmatite . . . 25
4. Coal and Iron Pit . . . 27
5. Mouth of the Pit . . . 28
6. Effects of Mining . . . 29
7. Roasting the Iron-stone in Kilns . . . 32
8. Ditto in heaps . . . 33
9. Section of Hot-blast Furnace . . . 36
10. Arrangement of Blast Pipes . . . 37
11. Blast Furnaces (*Staffordshire*) . . . 39
12. Mouths of Blast Furnaces . . . 39
13. Section of Blowing Apparatus . . . 40
14. Section of the Hearth . . . 41
15. Casting . . . 44
16. Section of Hot-blast Apparatus . . . 50
17, 18, 19. Water Apparatus for Tuyere . . . 53
20. Section of Finery Furnace . . . 54
21. Section of Puddling Furnace . . . 57
22. Puddling . . . 58
23. Shingling Hammer . . . 60
24. Puddle-ball Rolls . . . 61
25. Shears . . . 63
26. Finishing, or Bar Rolls . . . 64

STEEL.

27. Oregrund Iron Marks . . . 2
28. Section of Cementing Furnace . . . 3
29. Mouth of ditto . . . 5
30. Tilt Hammer . . . 7
31. Faggot . . . 8
32. Tilting Steel . . . 9
33. Preparing Crucibles for Cast Steel . . . 11
34. Crucible, or Melting Pot . . . 11
35, 36. Mould and Core . . . 12
37. Drawing the Crucibles . . . 14
38. Teaming . . . 15

IRON AND STEEL MANUFACTURES.

39. Section of Cupola Furnace . . . 18
40. Flask Casting . . . 20
41. Rammer . . . 20
42, 43. Screw and Trowel . . . 21
44. View of the first Iron Bridge . . . 22
45. Half Cylinders . . . 22
46. Cylinder and Core for Casting Pipes . . . 23
47. Casting Pot . . . 23
48, 49, 50. Mould and Core for Loam Casting . . . 24
51. Bending the Tire for Railway Carriage Wheel . . . 26
52. Ring Furnace . . . 27
53. Parts of Railway Carriage Wheel . . . 28
54. Casting the Nave . . . 28
55. The Slide Rest . . . 31
56. Illustrations of Planing Tools . . . 32
57. Iron Shaving . . . 33
58. Planing Machine . . . 34
59. Nail Forge . . . 37
60. Rose Sharp . . . 41

IRON AND STEEL MANUFACTURES—*Continued.* PAGE

61—68. The Rose, Clasp, Clout, Counter-clout, Fine Dog, Kent-hurdle, and Rose-clench Nails . . . 42
69, 70. Horse-Nail and Brad . . . 43
71. Sparrabies . . . 44
72. Cutting Machine . . . 45
73. Strip of Iron on Rod . . . 45
74. Nail-Cutting Machine . . . 46
75. Flat Strip for Nails and Brads . . . 47
76. Cntting the Nicks of Screws . . . 49
77. Cutting the Worm . . . 49
78. Arrangement of Cutters . . . 50
79. Screw-Cutting Lathe . . . 51
80. Screw-Cutting Dies . . . 51
81, 82, 83. Action of Improved and Defective Thread . . . 52
84. Screw-Cutting Machine . . . 53
85. Twisted Gun Barrel . . . 56
86. Cast Bullets . . . 59
87. Interior of Proof House . . . 60
88. Gun-Barrels burst in Proving . . . 61
89. Steel Rollers for Wire-Drawing . . . 68
90. Wire-Drawing Bench . . . 70

NEEDLES, FILES, AND CUTLERY.

91. Cutting the Wire into lengths . . . 5
92. Lengths in Rings . . . 5
93. Straightening . . . 6
94. Pointing on a Dry Stone . . . 7
95. Piercing the Eyes . . . 10
96, 97, 98. Pointed Wire and Eye, blind and perforated . . . 11
99, 100. Wires spitted and arranged for Heading . . . 12
101. Roll for Scouring . . . 13
102. Scouring Machine . . . 14
103. Drilling and Polishing . . . 16
104. Factory at Redditch . . . 18
105. Cutting Files . . . 24
106. File Cutter's Tools . . . 25
107. Hardening Files . . . 27
108. Cutting-out Saws . . . 34
109. Cutting the Teeth . . . 35
110, 111, 112, 113. Teeth of Mill-Saw, Pit-Saw, Hand-Saw, and Cross-cutting Saw . . . 35
114. Setter's Anvil . . . 39
115. Setting the Teeth . . . 40
116. Forging Table Knives . . . 47
117, 118. Pen-knife Blade, and Mould for a Fork . . . 49
119, 120. Stamping Spoon-Fork, and result . . . 50
121. Grinding Cutlery . . . 54
122. Arrangement of Table-knife for Grinding . . . 58
123. Preparing Ivory Handles . . . 60
124. Cutlery Workshop . . . 61
125. Drill and Shield . . . 61
126, 127, 128. Piercer, Boring-stick, and Breastplate . . . 62
129. Bending Carriage Springs . . . 63
130. Testing Springs . . . 64

COPPER, TIN, LEAD, AND ZINC.

131. Plan and Section of Part of the Main Lode in Dolcoath Mine . . . 2
132. Old Low Peak Measure . . . 30
133, 134. Interior of Mine—Shafts and Galleries . . . 37
135. „ Timbers, head and floor . . . 40
136, 137. „ Setting a Shot—Bottom of Shaft . . . 41
138. Exterior of Dolcoath Mine . . . 48

COPPER, TIN, &c. AND THEIR MANUFACTURES.

139. Dressing the Ore—Buddling . . . 4
140, 141. „ Tossing, or Tozing and Tub . . . 5

COPPER, TIN, &c. AND THEIR MANUFACTURES—*Continued.* PAGE

142. Dressing the Ore—Tying. 7
143, 144. „ Jigging by Hand and by Machine 8
145. „ Framing or Racking 9
146, 147. Section and Plan of Tin Smelting Furnace 13
148. Copper Rolling Mill 23
149, 150. Section and Plan of Zinc Smelting Furnace 26
151. Filling Crucible for Brass 28
152. Casting Brass Ingots 29
153. An Original Bolton and Watt Engine 31
154. Cutting out Blanks for Buttons 33
155. Rounding the Edges 35
156. Shanking 36
157. Cleaning 37
158. Gilding—Mercury Cage 38
159. Burnishing 39
160. Woven Fabric for Covered Buttons 40
161—167. Details of Covered Buttons 41
168, 169, 170. Mould, Punch, and Die 42
171. Preparing Wire for Pins 44
172. Pointing the Wires 45
173. Heading 47
174. Bent Tin Plate 50
175. Arrangement of Pots for Tinning 52

POTTERY, PORCELAIN, AND ENCAUSTIC TILES.

176. Ancient Pottery in a Tumulus 3
177—180. Sepulchral Urn—Decorated Urn—Roman Amphora—Egyptian unglazed Pottery 4
181, 182. Urn and Vase 5
183—188. Grecian Vases 6
189. Wedgwood's Factory at Etruria 11
190. Blunging the Clay 23
191. Grinding ditto 24
192. Mill for ditto 25
193. Flint Mill 26
194. Flint Pan 27
195. Section of ditto 28
196. Mixing the Ingredients 30
197. Slip Kilns 31
198. Throwing 35
199. Details of Throwing a Vase 36
200—204. Ditto ditto 37
205, 206. Pressing Handles 39
207, 208, 209. Moulds for Hollow-ware pressing 42
210. Hollow-ware Pressing 43
211. Biscuit Kiln 47
212. Seggar 52
213. Watches, Cockspurs, Triangles, and Stilts 53
214. Printing Stone Ware 55
215. Painting Porcelain 59
216. Whirler 60
217. Burnishing 61
218. Tile Press 63
219. Filling in Face of Tile 65
220. Whirler 65
221. Pressing and Scraping Tile 65
222, 223. Specimens of Tiles 66

GLASS.

224. The Glass House 2
225. Glass Pots 18
226. Mouth of the Furnace 18
227, 228. Flint Glass Bottle-mould and Blowing Bottles 20
229—233. Glass-blower's Tools 22
234. Glass-blower at Work 23
235. Mouth of Annealing Oven 24

LEATHER, PARCHMENT, AND GLUE. PAGE

236. Tan-pits 2
237. Lime-pits—Unhairing Hides 11
238. Finishing Hides 14
239, 240. The Currier's Knife. The Beam Man 18
241. The Sumach Tub 24
242. Finishing Thin Leather 25
243. Skin-splitting Machine 26
244. Tawing Drum 28
245. Staking Tawed Leather 29
246. The Herse for Parchment 36
247, 248. Scraping and Half-moon Knife 37
249. Grinding and Draining 38
250. Glue Boiling 42
251. Cutting out and distributing the Glue 44
252. Glue-maker's Field 45
253. Scouring 46

SUGAR.

254. Filling Sugar Moulds 2
255. Planting the Sugar Cane 11
256. Field of Sugar Cane 12
257. Cane Harvest 13
258. The Boiling House 15
259. Blow-up Cisterns 24
260. Bag Filters 26
261. Charcoal Filters 27
262. The Vacuum Pan 30
263. Proof Stick 31
264. Turning the Sugar Loaves 35
265. Sugar Oven 36

SULPHURIC ACID—SODA.

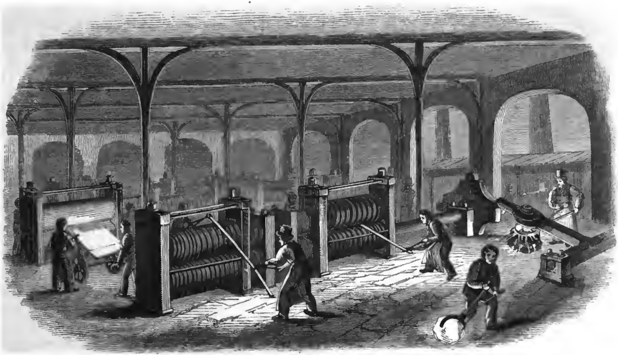
266. Early Method of Manufacture 7
267. Rough Distillation of Sulphur 10
268. Sulphuric Acid Chambers 16
269. Section of ditto 18
270, 271. Details of ditto 19
272. Portion of side of Chamber 21
273. Lead Pipe Siphon 22
274. Platinum Worm Siphon 24
275. Soda Crystallizing House 26
276. Section of Decomposing Furnace 33
277. Range of Furnaces 34
278. Black Ash Vats 36

COAL GAS.

279, 280. Section of the general and accidental features of a Coal Field 7
281. Plan of Panel Work 13
282. Section illustrating a Creep and a Crush 15
283. Safety Lamp. The Davy 20
284, 285. Ventilating arrangements 21
286. Dumb Furnace 22
287. Ventilating Cowls 23
288. The Retort House (*Westminster Gas Works*) 24
289, 290. Mouth Pieces of Retorts 29
291. Details of Gas Making from the Retorts to the Gasometer 30
292, 293, 294. Circular, Elliptical, and Kidney-shaped Retorts 31
295. Pressure Gauge 37
296. Dry Lime Purifier 39
297. Water Valve Cock 40
298. Gasometers 44
299. Telescope Gasometers 45
300. Pressure Indicator 48
301. The Governor 49
302. Section of Gas-meter 50
303. Section of Flame of Candle 53

Digitized by Google

Digitized by Google



THE FORGE—(COLEBROOKE DALE COMPANY'S WORKS AT HORSE HEY).

THE MANUFACTURE OF IRON.

THE splendid colour of GOLD, its great density, its imperishable nature, and its comparative scarcity, have obtained for it the epithet of *precious*, although, in point of utility to man, IRON has far higher and more numerous claims to such a title. Its ore, scattered through the crust of the earth in inexhaustible profusion,—often in immediate connexion with the fuel requisite for its production, and the limestone which facilitates that production,—"is an instance of arrangement, so happily suited to the purposes of human industry, that it can hardly be considered as recurring unnecessarily to final causes, if we conceive that this distribution of the rude materials of the earth was determined with a view to the convenience of its inhabitants." *

The innumerable applications of iron in our own day result from the various useful properties of this metal; it can be brought to a fluid state, and made to assume whatever form has been given to the mould designed for its reception; it can be drawn out into bars of any required degree of strength, or into wires of any required degree of fineness; it can be spread out into plates or sheets; it can be twisted and bent in all directions; it can be made hard or soft, sharp or blunt. Iron may be regarded as the parent of agriculture, and of the useful arts; for without iron, the ploughshare could not have rendered the earth fertile, nor could the machines for constructing machinery have been successfully produced. Iron furnishes the scythe and the pruning-hook, as well as the sword and the cannon; it forms the chisel, the needle, the graver, and springs of various kinds, from the spring of a watch to that of a carriage; the chain, the anchor, and the compass, all owe their origin to this most useful of all the metals. We can scarcely move without meeting with new and surprising proofs of the fact, that we are, indeed, living in the age of iron. We travel by land on iron railroads, drawn by horses of iron; we pass over bridges constructed of iron, and often suspended by iron rods; our steam-boats are of iron; our bedsteads, chairs, stools, and ornaments are frequently of iron; clumsy wooden gates are superseded by light and elegant structures of iron; buildings of all kinds are supported on pillars of iron; and, to crown all, we build houses and light-houses of iron, and transport them in pieces to distant parts of the globe.

---

* CONYBEARE, *Geology of England and Wales.*

Iron, therefore, performing so important a part in the progress of civilization, may well deserve a somewhat extended notice; and it is proposed, without departing from the plan of former treatises, to preface the account of the manufacture with a somewhat detailed account of the metal, from the earliest times.

HISTORICAL NOTICES OF IRON.

In the early history of the world, the use of iron seems to have been known; for we read (Gen. iv. 22) of Tubal Cain, an instructor of every artificer in brass and *iron*. From an expression in Deuteronomy (iv.

20), "The Lord hath brought you forth out of the *iron furnace*, even out of Egypt," it appears more than probable that the smelting and working of iron was commonly practised in that country. In the same book, Palestine is described as "a land whose stones are *iron*, and out of whose hills thou mayest dig brass" (Deut. viii. 2). There are, also, several passages in the four books of the Mosaic law, which prove that iron was well known. The bedstead of Og, king of Bashan, was of iron (Deut. iii. 11). Iron tools were used in the hewing and squaring of stones (Deut. xxvii. 5). Saws, harrows, and axeheads, were of iron; and it is probable that offensive weapons were made of the same metal, because it is stated in the Mosaic law, that "if any one strike another with an instrument of *iron* so that he die, he is a murderer." The chariots of the Philistines were of iron (Judges i. 19). And Jabin, king of Canaan, reduced the Israelites to subjection by means of his nine hundred chariots of iron (Judges iv. 3). "These chariots were probably war-carts, with perhaps scythes attached to the axles of their wheels, such as were in use by the sovereigns of Assyria and Mesopotamia, and whose charge on level ground could not fail of being extremely formidable to infantry, of which the Israelitish armies, before the appointment of kings, appear entirely to have consisted." * Goliath is represented as wearing bronze armour, and a spear pointed with iron; and in the hymn of victory composed by David, after the reduction of all his enemies, mention is made of a bow of steel (2 Samuel xxii. 35).

Previous to the Babylonian conquest, the Jews were acquainted with two kinds of iron; namely, that in common use, and a superior sort, known by the name of *northern iron*. Thus, in Jeremiah

---

* Aikin, *Antiquarian History of Iron*, in the Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce.

(xv. 12), "Shall iron break the northern iron and the steel?" Mr. Aikin thinks that the *steel* here meant, was the produce of the countries east of Babylonia. In the "Lamentation for Tyre," contained in the book of Ezekiel (xxvii. 12—19), the different countries are enumerated with which that great emporium traded, and the commodities which she imported from them. It is declared of Tyre, that "Tarshish was thy merchant, by reason of the multitude of all kind of riches; with silver, iron, tin and lead, they traded in thy fairs." It is generally agreed, that by Tarshish is meant Spain; the maritime town of Tartessus, at the mouth of the Guadalquiver, still affording some probable indication of the name. "It was probably in part from Celtiberia, and in part from Catalonia, a district between the lower Ebro and the Pyrenees, celebrated in all times for its iron, that this metal was imported to the Tyrian markets: and I may observe here, that the old Catalonian method of obtaining bar-iron directly from the ore, without going through the usual process of smelting, and which, even now, is hardly obsolete in that province, is, from its character of rude simplicity, not unlikely to be the very process made use of for the supply of the Tyrian market, 2,300 years ago."

It is mentioned in another passage—"Dan also, and Javan, going to and fro, occupied in thy fairs; *bright iron,* cassia, and calamus, were in thy market."

The term *bright,* applied to this iron, seems to distinguish it from common iron, and the same merchants who brought this, brought also cassia and calamus, two aromatic substances, probably obtained from the countries to the east of Persia, whence they were brought by land carriage in caravans "going to and fro." If this *bright iron* were the common malleable form of the metal, it could never have entered into competition with the iron of Tarshish, conveyed by water carriage; we may, therefore, I think, without any great chance of error, regard it as the *northern* *iron*, or steel, already mentioned, susceptible of a bright polish, and perhaps not differing from the *wootz* of modern India.

Among the ancient Greeks bronze seems to have preceded the use of iron; and the term used to designate the smith's calling signified a "worker in bronze;" a term which, in the course of time, came to be applied to workers in iron also. Iron is frequently mentioned by Hesiod, who characterizes the four ages of the human race as the golden age, the silver age, the brazen age, and the *iron* age. The uses to which iron was applied are noticed in many passages of Homer. "Iron was used for felling-axes, for double-headed axes for slaughtering cattle, for shipwrights' tools, for the axles of chariots, for pointing ploughs, for sheep hooks, and agricultural implements. In exchange for cargoes of wine supplied to the camp before Troy, bronze and iron were given. Among the spoils gained by Achilles in sacking the towns of the Trojan allies, were gold, ruddy bronze, and white iron." And to remove all doubt as to the correct rendering of the word *σίδηρος* into iron, Mr. Aikin quotes the following simile from the Odyssey:—"As some smith * plunges into cold water a loudly-hissing great hatchet or adze, tempering it, for hence is the strength of iron:" clearly proving that the art of tempering steel was practised just as it is at the present day for common cutting tools, and that the worker in iron or steel was called a *brazier*.

The use of iron is also noticed by Herodotus, Æschylus, and other Greek writers. About the time of Æschylus (who was born 460 years B.C.), steel of excellent quality seems to have become so abundant in Greece, as to have superseded the use of bronze for swords and other offensive arms. "In the imperfect geography of the Greeks, all the countries on the shores of the Black Sea, and thence indefinitely northward and eastward, were confounded together under the general term *Scythia;* hence Chalybian and Scythian are used by Æschylus indifferently. He speaks of the Chalybes as workers in iron, of Scythia as a land the mother of iron; and of the sword as 'sharp iron, the bitter appeaser of strife, the Pontic stranger born in fire,' and also as 'the Chalybian stranger come out of Scythia.' From this time dates the use of the word *chalybs,* in Greek, as signifying steel of the best quality; whence it passed, unchanged, into the Latin language, and may at the present day be recognised in our own in the expression *chalybeate* waters, *chalybeate* medicines, &c., in consequence of some commercial transactions which took place more than twenty-three centuries ago, between Greece and a country on the Black Sea."

---

* "Worker in bronze" is the original word.

Aristotle seems to have entertained the incorrect notion that steel was only the purest state of iron. He says:—"Steel is made by melting wrought iron, and then letting it become solid; for by this means the scoriæ are purged away. By repeating this process several times the iron becomes steel; this method, however, is not often practised, on account of the great loss of weight which the iron undergoes; but the iron becomes the better the less impurity it contains."

Among the Romans the use of iron seems to have been known at an early period of their history. Polybius, the earliest historian of Rome, notices the military use of iron, by which it appears that the helmet and breast-plate of the Roman soldiers were of bronze, but the shield had a boss of iron, and an outer border of the same; the sword was a strong cut-and-thrust blade, of Spanish steel, and the spear was pointed with iron. Diodorus Siculus and Pliny the Elder are among the earliest writers on the manufacture of iron. The former mentions Æthalia (Elba), which is even now celebrated, as it was then, for the richness and abundance of its iron ore. Dio-

Google

dorus says, "The natives dig and cut out of the ground the ironstone, to melt, in order for the making of iron; much of which metal is in this sort of stone. The workmen employed first cut the stone in pieces, and then melt them in furnaces built and prepared for the purpose. In these furnaces the stones, by the violent heat of the fire, are melted into several pieces, in form like great sponges, which the merchants buy by truck and exchange of other wares, and export them to Dicæarchea and other mart towns. Some of these merchants that buy of these wares cause them to be wrought by the coppersmiths, who beat and fashion them into all sorts of tools, instruments, and other shapes and fancies; some they neatly beat into the shape of birds, others into spades, hooks, and other sorts of utensils—all of which are transported and carried about into several parts of the world by the merchants."

Pliny, in his *Natural History*, speaks of iron as "a metal which we may well say is both the best and the worst implement used now in the world; for, with the help of iron, we break up and tear the ground; we plant and plot our groves; we set our port-yards, and range our fruitful trees in rows; we prune our vines, and by cutting off the superfluous branches and dead wood, we make them, every year, to look fresh and young again. By means of iron and steel, we build houses, hew quarries, and cut in stone; yea, in one word, we use it to all other necessary uses of this life. Contrariwise, the same iron serveth for wars, murders, and robberies; not only to offend and strike therewith in hand, but also to reach and kill afar off, with divers sort of darts and shot; one whiles discharged and sent out of engines, another while launched and flung by the force of the arm; yea, and sometimes let fly with wings. This I take to be the wickedest invention that ever was devised by the head of man; for, to the end that death may speed away the faster to a man, and surprise him more suddenly, we make it to fly as a bird in the air, and to the arrow, headed at one end with deadly iron, we set feathers at the other, whereby it is evident that the mischief proceeding from iron is not to be imputed to the nature of it, but to the unhappy wit of man."

The same writer states, that in Calabria, near the sea-shore, there is an entire mountain of iron ore; but the chief seats of the manufacture in Spain, while the Romans possessed the country, were in Celtiberia, which included part of the present provinces of New Castile and Aragon. The town of Bilbilis seems to have been in the centre of the forges, and the river Salo, which falls into the Ebro, was celebrated for giving a high temper to steel, on account of the coldness of its waters.

Pliny enumerates different qualities of iron, and esteems *Seric* iron (from the remote east) as the best of all, while next in goodness is the *Parthian* iron, and next to that the iron of *Noricum* (Styria). He refers to the *magnet stone* as being found in Calabria. "Iron," he says, "is the only metal which receiveth strength from that stone; yea, and keepeth the same a long time, insomuch, as by virtue thereof, if it be once well touched and rubbed withal, it is able to take hold of other pieces of iron; and thus, otherwhiles, we may see a number of rings hanging together in manner of a chain, notwithstanding they be not linked and enclosed one within another."

Although iron was so well known to the Romans, yet it appears by the evidence afforded by the excavations of Pompeii and Herculaneum, that articles of bronze were in general use in the middle of the first century, when these cities were overwhelmed by a great eruption of Vesuvius. "It is true, that iron instruments may have been destroyed by rust, during their long sepulture of near seventeen centuries; but, if such ever existed, the wonder and difficulty still remain how bronze and iron should ever be considered as equally applicable to the same uses. In all the Latin writers *ferrum*, iron, is the most common name for a sword, but the swords which have been found in these towns are of bronze, as also are the points of spears. Pole-axes and other sacrificing instruments have been found of the same material; even surgeons' instruments, forty in number, some with cutting edges, and all of bronze, were discovered."

The earliest method of smelting iron ore seems to have been in furnaces erected on the summits of hills for the sake of the currents of air. The furnaces were perforated on all sides with holes, through which the air was driven when the wind blew. Mungo Park, in his *Travels in Africa*, describes one of these furnaces, which is supposed to have been constructed on the ancient model. During his stay at Kamalia the smelting furnace was at a short distance from the hut where he lodged. It was a circular tower of clay, about ten feet in height and three feet in diameter, surrounded in two places with withes to prevent the clay from falling to pieces by the heat. Round the lower part, on a level with the ground (but not so low as the bottom of the furnace, which was somewhat concave), were seven openings, into each of which were placed three tubes of clay, and the openings again plastered up in such a manner that no air could enter the furnace but through the tubes, by the opening and shutting of which the fire was regulated. He describes the ironstone as being very heavy, and of a dull red colour with greyish specks; it was broken into pieces about the size of a hen's egg. A bundle of dry wood was first put into the furnace, and covered with a considerable quantity of charcoal; over this was laid a stratum of ironstone, and then another of charcoal, and so on until the furnace was quite full. The fire was applied through one of the tubes, and blown for some time through bellows made of goats' skins. The operation went on very slowly at first, and it was some hours before the flame appeared above the furnace; but after this it burnt with great violence all the first night; and the people who attended it put in at times more charcoal. The next day the fire was not so fierce, and on the second night some of the tubes were withdrawn, and the air allowed to have freer access to the furnace; but the heat was still very great, and a bluish flame rose some feet above the top of the furnace. On the third day all the tubes were taken out, the ends of many of them being vitrified by the heat; but the metal was not removed until some days afterwards, when the whole was perfectly cool. Part of the furnace was then taken down, and the iron appeared in the form of a large irregular mass, with pieces of charcoal adhering to it. It was sonorous; and when any portion was broken off, the fracture exhibited a granular appearance like broken steel. The owner stated that many parts of this cake were useless, but that there was still enough of good metal to repay him for his trouble. This iron, or rather steel, is formed into various instruments, by being repeatedly heated in a forge, the heat of which is urged by a pair of double bellows, of a very simple construction, being made of two goats' skins, the tubes from which unite before they enter the forge, and supply a constant and very regular blast. The hammer, forceps, and anvil were all very simple, and the workmanship (particularly in the formation of knives and spoons) was not destitute of merit. The iron was hard and brittle, requiring much labour in the working.

The following remarks afford a good commentary on the above description :—

" The practice of these air bloomeries must have been slow in the extreme. A long and continued cementation of the ore in contact with the fuel, must in the first instance have been necessary to dispose the metallic particles to unite. A too rapid exposure to a high temperature would be apt to unite a considerable portion of oxygen with the ore, which in this way would acquire a considerable degree of fusibility: this would not only diminish the quantity and quality of the iron, but retard the general operation. To render the quality of the iron homogeneous, masses of iron ore would be used as nearly of one size as possible, which would give rise to a rejection, in part, of the small or dust ore, generally the richest of the vein. That this practice prevailed to a considerable extent in Gloucestershire is evident from the large quantities of small mine * found from time to time in the old caverns or weeldons of the mountain limestone formation. These acknowledged evils undoubtedly affected the economy and prosperity of the trade, until some more fortunate or more ingenious worker applied the bellows to the art of iron making, which gave rise to the blast blowing, and occasioned a great revolution and improvement in the fabrication of that valuable and highly useful metal." †

A furnace similar to the above was probably used by the ancient Britons at a very early period. Some historians suppose that the Britons obtained their knowledge of the art of smelting iron during their intercourse with the Phœnicians, who traded with them for tin. This intercourse appears to have lasted about 300 years, when it was interfered with by the Greeks about 330 B.C. The tin ingots were conveyed from Cornwall to the Isle of Wight, and sold to the foreign merchants who resorted there.

Diodorus Siculus, speaking of the Britons of the Land's End, Cornwall, says that "they live in a very hospitable and polite manner, which is owing to their great intercourse with foreign merchants." Cæsar also states that, before his time, the trade of Britain, being carried on by the Gauls, the greatest

---

* The ore is commonly called *mine* by the workmen.

† MUSHET, *Papers on Iron and Steel.*

number of ships from the continent came to the Kentish ports, whose inhabitants were the most polite and conversant with foreign merchants. Strabo mentions iron as one of the exports of Britain. So that it seems to be tolerably clear that, prior to the Roman invasion, the Britons had discovered or been taught the art of working iron. That such was the case is further proved by the vigorous resistance offered by the Britons to their Roman invaders. Their war-chariots were armed with scythes and hooks, and their cavalry were furnished with broadswords and spears.

When once the Roman conquest was secure, the arts were carried on to an extent before unknown in the island. After the arrival of Adrian (A.D. 120), the *fabrica*, or great military forge, was established at Bath; and similar establishments were formed in different parts of the country. "Bath would be a spot of all others calculated for such an edifice; contiguous to the hills of Monmouthshire and Gloucestershire, where iron ore was found in the utmost plenty, and centrical in situation for the distribution of the arms which were made at its furnaces, to every part of the kingdom." *

The successors of Adrian continued to work the iron mines till the final abandonment of Britain by the Romans about A.D. 409. Immense beds of iron cinders, left by the Romans, have been discovered in the forest of Dean in Monmouthshire, in Yorkshire, and other countries, among which have also been found Roman coins, and the remains of altars inscribed to the god who presided over iron. Many of these heaps are also called *Danes' Cinders*, from the idea, probably a correct one, that during the occupation of England by the Danes, the smelting of iron was carried on largely by that people. From the rude method of smelting in these early times, a portion only of the ore was reduced, and it has been found profitable, in modern times, to smelt these cinders over again. For nearly 200 years the blast furnaces in the Dean forest used nearly one half of the furnace burden of these slags or cinders, which were found highly advantageous to mix with the calcareous ores of the district.*

---

* SCRIVENOR, *History of the Iron Trade*, 1841.

Scarcely any mention is made of iron in the interval between the Saxon and the Norman conquest. The Anglo-Saxons bestowed especial honour on artificers who excelled in fabricating swords, arms, and defensive armour, all persons being required by law to have arms. According to Camden, the chief trade of the city of Gloucester before and at the time of the Norman conquest, was the forging of iron; and it is mentioned in Doomsday-book, that scarcely any other tribute was required from that city, than thirty-six *dicars* † of iron, and 100 iron rods, for nails or bolts, for the use of the royal navy. Gloucester was supplied with iron from the forest of Dean.

From the conquest to the death of John, iron and steel were imported from Germany and other countries; the "German merchants of the steel yard" probably deriving that title from the article imported by them, and sold at a place called "The Steel Yard." The art of making defensive armour was, during this period, carried to great perfection, and a smith or armourer was considered a necessary appendage to the establishment of every knight.

During all this time, the fuel used in smelting iron was wood charcoal, the use of coal coke being unknown. Hence the iron mines were all situated in the wooded districts of England. Iron mines were almost unknown in the north of England, and the metal was of course very scarce and highly prized. In a predatory expedition made by the Scots in the tenth year of Edward II.'s reign, no iron was found worth seizing until they came to Furness in Lancashire, where they discovered a quantity manufactured, which they preferred to all other plunder. In consequence of this scarcity of iron, its exportation was prohibited in the twenty-eighth year of Edward III.

---

* MUSHET.

† A *dicar* contained ten bars.

Hitherto all articles of iron had been forged, the art of casting not having yet been invented; nor is it easy to determine when castings first came into use. Cannon are mentioned as early as 1327, and are supposed to have been first used in England by Edward III. in his invasion of Scotland. They were first made on the same principle as coopers construct their barrels: "a number of iron bars fitting as close as possible to each other, were arranged round a cylinder of wood, and were then bound together by strong iron hoops, when the wood being driven out, there remained an iron pipe which formed the barrel. This mode was superseded by casting the cannon of bronze; and at the end of Queen Elizabeth's reign, it is said, the English first attempted to substitute iron for bronze, being induced thereto by the greater cheapness of the latter material, by its greater strength to resist the explosion, and by its greater infusibility, which secured such pieces of ordnance from running at the touch-hole."

During the fourteenth and fifteenth centuries, England was supplied with various manufactures of iron and steel, by Germany, Prussia, and Spain: but, as the home manufacture had considerably improved, the manufacturers of London and other towns, thinking the competition of foreigners to be a grievance, presented a petition to the House of Commons, in 1483, complaining thereof; whereupon an act was passed, prohibiting the importation of knives, hangers, tailor's shears, scissors, andirons, fire-forks, gridirons, stock-locks, keys, hinges, garnets, spurs, bits, stirrups, buckler-chains, latten-nails with iron shanks, buckles for shoes, shears, iron-wire, iron candlesticks, grates, &c.

Google

The great and increasing demand for iron caused the extension of iron works to different parts of the island. Camden states, that "Sussex is full of iron mines everywhere, for the casting of which there are furnaces up and down the country, and abundance of wood is yearly spent; many streams of water are drawn into one channel, and a great deal of meadow ground is turned into pools for the driving of mills by the flushes, which beating with hammers upon the iron fill the neighbourhood night and day with their noise. But the iron here wrought is not everywhere of the same goodness, and in general more brittle than Spanish iron. It yields, however, no small profit to the proprietors of the mines, who cast cannon and other articles in it." At the time when Camden wrote, Sheffield had become "remarkable, among many other places hereabouts, for blacksmiths, there being much iron digged up in these parts;" and it is curious to mark in the following passage from the same writer the ignorance of the inestimable value of the coal and iron formations of Staffordshire. Referring to this county, he says:—"The south, which has much pit-coal, and mines of iron, but whether more to their loss or advantage, the natives themselves are the best judges, and so I refer it to them."

The vast consumption of wood by the iron smelters had occasioned so great a scarcity of that article, that in the first year of Elizabeth's reign an Act was passed by which it was enacted, that no timber of the breadth of one foot square at the stub should be cut down for the purpose of making charcoal for the iron manufacture in any place within fourteen miles of the sea, or of any navigable stream, except in the county of Sussex, in the weald of Kent, and a few other places specified. In 1581 a further Act was passed limiting the erection of iron works, stating as a reason that "the necessary provision of wood, as well as timber fit for building, and other uses, as also all other fellable timber serving for fuel, doth daily decay and become scant, and will, in time to come, become much more scarce, by reason whereof the prices are grown to be very great and unreasonable." Four years later an Act was passed prohibiting the erection of any new iron works in Surrey, Kent, and Sussex, and forbidding the use of timber of the size of one foot square at the stub as fuel at any iron work.

It was not till the scarcity of charcoal had stopped many iron works, that attempts were made to use pit-coal in the smelting furnace. Pit-coal had been wrought at Newcastle, prior to the year 1272, and vast quantities were annually exported to Holland and the Low Countries for the use of the smithy. In England, however, strong prejudices existed against its application to the manufacture of cast or malleable iron, as will be seen by the following details.

Many persons during the reigns of James I. and Charles I. attempted to use coal, but none were successful except Dud Dudley, who says:—"Having former knowledge and delight in iron works of my father's when I was but a youth, afterward, at twenty years old, was I fetched from Oxford, then of Baliol College, anno 1619, to look over and manage three iron works of my father's, one furnace, and two forges, in the chase of Pensnet, in Worcestershire; but wood and charcoal growing very scanty, and pit-coals in great quantities abounding near the furnace, and to attempt, by my new invention, the making of iron with pit-coal, assuring myself in my invention, the loss to me could not be greater than others, nor so great, although my success should be fruitless; but I found such success at first trial as animated me; for, at my trial, or blast, I made iron to profit with pit-coal, and found *facere est addere inventioni.* After I had proved by a second blast and trial the feasibility of making iron with pit-coal and sea-coal, I found by my new invention, the quality to be good and profitable, but the quantity did not exceed above three tons per week, though I doubted not in future to have advanced my invention to make quantity also."

Application was made to James I. for a patent for this invention, which was immediately granted for thirty-one years; but in the year after the date of the patent, Dudley's iron works were destroyed by a great flood, "to the joy of many iron-masters, whose works escaped the flood, and who had often disparaged the author's inventions, because the author sold good iron cheaper than they could afford it, and which induced many of the iron-masters to complain unto King James, averring that the iron was not merchantable. As soon as the author had repaired his works and inventions, to his no small charge, they so far prevailed with King James, that the author was commanded, with all speed possible, to send all sorts of bar-iron up to the town of London, fit for making of muskets and carbines; and the iron being so tried by artists and smiths, that the iron-masters and iron-mongers were all silenced until the twenty-first of King James." In this year all monopolies were put an end to, except the patent just mentioned, which was, however, limited to fourteen years. "After which act the author went on cheerfully, and made annually great store of iron, good and merchantable, and sold it at 12*l.* per ton. I also made all sorts of cast-iron wares, as brewing-cisterns, pots, mortars, and better and cheaper than any yet were made in these nations with charcoal."

The opposition of the iron-masters at length prevailed, and poor Dudley was turned out of his iron-works; on what ground, however, does not appear, for he says it would be "over long to relate." He then proceeded to Himley furnace, in Staffordshire, where he made much iron with pit-coal; "but wanting a forge to make it into bars, was constrained for want of stock to sell the pig-iron unto the charcoal iron-masters, who did him much prejudice." After this he erected a large furnace, "twenty-seven feet square, all of stone," at Hascobridge in Staffordshire, where he made seven tons of iron per week, "the greatest quantity of pit-coal iron that ever yet was made in great Britain. Near which furnace the author discovered many new coal mines, ten yards thick, and iron mine under it, according to other coal works; which coal works being brought unto perfection, the author was by force thrown out of them, and the bellows of his new furnace and invention, by riotous persons, cut in pieces, to his no small prejudice, and loss of his invention of making of iron with pit-coal, &c.; so that being, with lawsuits and riots, wearied and disabled to prosecute, his art and invention at present, even unto the first patent, was extinct."

The subsequent history of Dudley is but a further illustration of the fate common to first inventors of a useful process or machine; he lost most of his property, and was imprisoned for debt. While he was thus engaged in law, the country was distracted by civil war; his claims were forgotten, and his voice was too weak to be heard in the general confusion; but he had the mortification of witnessing the grant of a patent by Cromwell to one Captain Buck, for making iron with pit-coal; and he states that Cromwell and many of his officers were partners in the scheme. The plan, however, proved a total failure. At the Restoration, Dudley presented a memorial to Charles II., which is exceedingly interesting, and contains a clear and masterly epitome of the state of the iron trade at the time, and also of the attempts to make iron with pit-coal. We can only find space for one extract from this document.

"God of his infinite goodness—if we will but take notice of his goodness unto this nation—hath made this country a very cranati, for the supplying these men with iron, coal, and lime, made with coal, which hath much supplied the men with corn also of late; and from these men, a great part not only of this island, but also of His Majesty's other kingdoms and territories, with iron wares, have their supply; and wood in these parts almost exhausted, although it were of late a mighty woodland country. Now, if the coals and ironstone so abounding were made right use of, we need not want iron as we do, for very many measures of ironstone are placed together under the great ten yards thickness of coal, and upon another thickness of coal, two yards thick, not yet mentioned, called the bottom coal or heather coal, as if God had decreed the time when and how these smiths should be supplied, and this island also, with iron; and most especially, that this coal and ironstone should give the first and last occasion for the invention of making iron with pit-coal, no place being so fit for the invention to be perfected in, as this country, for the general good; whose lands did formerly abound in forests, chases, parks, and woods, but exhausted in these parts."

Dudley does not seem to have succeeded in his application, and with one exception, the attempt to produce iron in large quantity was gradually forgotten. The failure does not seem to have arisen from an ignorance of the art of converting coal into coke, for Dr. Plot, in his History of Staffordshire (published 1686), says: — "They have a way of charring the coal, in all particulars, the same as they do wood, whence the coal is freed from noxious steams, &c. The coal thus prepared they call *cokes*, which conceives as strong a heat almost as charcoal itself, and is as fit for most other uses, but for melting, fining, and refining of iron, which it cannot be brought to do, though attempted by the most skilful and curious artists."

It was not till the early part of the next century that attempts to substitute pit-coal for charcoal were renewed. In 1713, Mr. Darby, of Colebrooke Dale,

Digitized by Google

was the first to use pit-coal; but the progress of the manufacture must have been slow, for, in the *Philosophical Transactions* for 1747, it is stated as a sort of curiosity, that "Mr. Ford, from iron ore and coal, both got in the same dale, makes iron brittle or tough as he pleases; there being cannon thus cast, so soft, as to bear turning like wrought iron."

The method of using the new fuel was many years in becoming generally known, during which, the quantity of iron produced became less and less, while the demand for it was every year increasing. Immense supplies were obtained from Russia and Sweden, and it was not until machinery became greatly improved, and the steam engine had imparted an almost irresistible strength to the arm of man, that the immense beds of coal and ironstone were made to operate upon each other in the production of iron.

While this change in fuel was operating, the manufacture became reduced to a very languid state, so much so, that by the year 1740, the number of furnaces had decreased to fifty-nine, being only three-fourths of their previous number; and their annual produce had fallen to 17,350 tons. This, however, was the lowest point of degradation, for as soon as the method of using coke instead of wood was understood, the manufacture revived; so that in 1788, the number of tons of pig-iron produced amounted to 61,300 tons; in 1796, the quantity was increased to 108,793 tons; in 1806, to 250,000 tons; in 1820, to 380,000 tons; in 1827, to 644,500 tons; in 1845, to 1,250,000 tons; and in 1851 the annual quantity was estimated at 2,500,000 tons.

By noticing the increasing quantity of iron produced by one furnace under the above dates, we obtain a striking illustration of the extent of the demand, and the vast improvements effected in the manufacture.

	ANNUALLY.			WEEKLY.		
	Tons.	Cwt.	Qrs.	Tons.	Cwt.	Qrs.
In 1740, the average produce of each furnace was . .	294	1	1	5	13	0
1788, ...	796	2	0	15	6	0
1796, ...	1,046	0	0	20	2	0
1827, ...	2,460	0	0	47	6	0
1845, ... estimated	5,200	0	0	100	0	0

In 1851, some of the Scotch and Welsh furnaces were each producing, on the average, as much as 200 tons weekly.

Thus in England alone, during little more than a century, the produce of iron has increased from seventeen thousand to two million and a half tons; and the yield of each furnace during the same period has been multiplied from twenty to forty fold.

The change in fuel also naturally affected the locality of the manufacture. In 1740, Gloucester produced a much larger quantity of iron than any other county in Britain. Sussex had the greatest number of furnaces; there were a few in Kent, and a few in the midland counties and along the Welsh borders. After the introduction of coke, the coal counties began to assume that rank in connexion with iron, which for so many ages had belonged to the woodland districts. Shropshire, Staffordshire, and South Wales rose into importance. For some years past the greatest quantity of iron has been produced in South Wales; while in point of skill in the production of a superior metal, Shropshire and Staffordshire have attained the highest excellence.

Thus "in whatever point of view the iron trade may be considered with regard to this country, the advantages derived from its progress have been great: whether we consider it as having cleared the country of vast tracts of wood—affording at the same time an ample indemnification for the labour bestowed—the consequent improvement of climate, and the spread of agriculture; as having placed us at the head of the manufacturing countries of Europe;

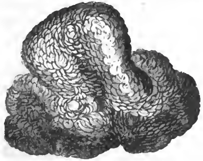
as affording us at all times a plentiful supply for the construction of every species of machinery; or, as having been a source of wealth to many individuals, and at the same time, affording a competent recompense for the labour of a number of our fellow-creatures."[*]

DISTRIBUTION OF IRON ORES—MINING OPERATIONS.

The profusion with which iron is scattered over the earth has been already alluded to. Its ores are very numerous, but not equally adapted to the purposes of the manufacture; for in some specimens the quantity of metal is too small for profitable working, while in others it is combined with substances which would injure the quality of the iron. All the ores at present used in the manufacture fall under two great divisions: the one including ores in which the iron is united with oxygen, and containing scarcely any other substance; and the other comprising those in which the oxide of iron is in union with carbonic acid, and is mixed with clay, lime, and other earths. Belonging to the first class is the *magnetic iron ore*, found chiefly in primitive countries; it is very abundant at Roslagen, in Sweden, where it is manufactured into a bar-iron, which is of great value in the making of steel. A second variety of native oxide of iron is called *iron glance, specular*, and *micaceous iron ore*. The beautiful iron ore of Elba belongs to this variety. A third variety is the *Hæmatite*, or *red ironstone*, which is abundant near Ulverstone, in Lancashire, and is much used in making iron for iron plate and wire. The second division is the source from which by far the greatest quantity of iron is obtained, not that the ores are, by any means, so rich in metal as those first noticed, but from the single circumstance of their being associated with the fuel required to smelt them.

[*] MUSHET.

The *clay ironstone*, or carbonate of iron, is the substance from which Staffordshire, Shropshire, Wales,



CARBONATE OF IRON, OR SPARRY IRON ORE.

Derbyshire, Scotland, and other parts of Great Britain, produce such enormous quantities of iron: and not only are these districts furnished with

HÆMATITE.

abundance of iron ore and coal, but generally, at no great distance there is the limestone for fluxing the ore, sandstone for building, and refractory fire clays for the furnaces.

The ironstone usually occurs in horizontal strata, subject, however, to the same inclination as the other strata which it accompanies. It is generally found imbedded in schistus clay, more or less compact, which moulders away when exposed to the air. The ironstone is met with under two different forms; in regularly connected strata called *bands*, and in strata of detached stone, formed in distinct masses, from the size of a small bullet to that of lumps of several hundred pounds weight. Small and middling-sized stones, and which generally have a flat ovular form, are called *ball stones;* those of great weight are named *lunkers.* In Staffordshire, a variety of local names are applied to the ironstone: when found in beds or seams, the miners call it *blue flats*, *blue clist*, and *whitestone:* when it is found in balls or lumps, imbedded in clay, the different qualities are expressed in terms which will convey little or no meaning to the reader, such as *clunch*, *binds*, *ironstone-bearer*, *penny-earth*, *gubbin-stone*, *poor robin*, &c.

A valuable ore, known as *black-band*, contains a quantity of carbonaceous matter in addition to the ordinary earthy substances which are found in all clay ironstones. This carbonaceous matter assists in the roasting of the ore.

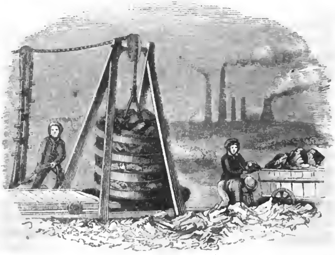
When the ironstone occurs near the surface, all that is necessary to procure it is, to remove the soil and earth; the stone then presents itself like a pavement, more or less inclined. It is easily raised by the application of wedges, bars, &c., but as all secondary strata descend, the stone of course becomes gradually buried under an accumulating depth of earth, which is more and more expensive to remove. Horizontal galleries are then perforated under the soil, to the extent of from 100 to 240 yards, so as to fall in with the declivity of the strata. In Scotland these galleries are called the *barrow roads.* When the miner has arrived at the end of one of these galleries, he turns round and commences an excavation on his right and left hand, proportioned to the rise and dip of the stone, to the extent of several yards on each side; the accompanying shale and rubbish are packed into the vacant space behind him, or it is wheeled to the mouth of the gallery along with the ironstone. In this way the miner clears out the whole ironstone contained in 100 to 240 yards in the length, and in 20 to 30 yards in width. The thickness of the band may not exceed four inches, but, if of good quality, this is quite sufficient to pay the expenses of working. The height of the gallery is commonly so small, that the miner is obliged to perform his work lying upon his side; the wheelers are likewise obliged to push the barrow on all fours. These galleries are cooler than coal mines at the same level; but they are also more wet and dirty. The chief danger to which the miner is exposed arises from the occasional falling in of a portion of the roof; there is little or no danger from noxious gases, such as occur in coal mines.

COAL AND IRON PIT.

When the galleries have been carried on for a certain length, the expense of wheeling out the stone becomes too great: a more economical method is therefore adopted. A pit is sunk at a spot from 160 to 200 yards farther on the same line of level, and when the ironstone is found, the miner sets off another gallery or barrow road towards his former working, and continues till he meets the termination of his old waste; then, as before, he returns, carrying off a similar portion of ironstone from each side of the gallery. The other side of the pit is next perforated, and when all the ironstone is obtained, another pit is sunk at a similar distance from the termination of the second gallery in the first, and this opens a new field of supply. This process is repeated until the field is totally exhausted.

These extensive excavations commonly collect a considerable quantity of water, which is removed in various ways, such as running a counter gallery as near to the declivity of the metals as possible, and passing the water into it: or the water is extracted from one general reservoir by means of pumps worked either by water wheels or by the steam engine.

When the ground is tolerably level, and the ironstone is at some depth, a pit is sunk at once from the surface. Galleries are run from this pit at different depths, for the purpose of working both the coal and the ironstone. In a pit near Wolverhampton, visited by the writer, the galleries were of sufficient height to allow a horse to work in them. The ironstone was loaded in small carriages, moving upon a railroad, and drawn by the horse to the mouth of the pit. Here a sort of circular platform was loaded



MOUTH OF THE PIT.

with the stone to a considerable height, the mass being supported by loose, flexible bands of iron. When drawn up to the top, a platform was wheeled over the mouth, upon which the load was rested while being unpacked. The ironstone is spread over the surface of the ground, in a heap two or three feet high, preparatory to its being roasted.

The appearance of an iron district which has been extensively excavated, is sometimes not a little curious: portions of the ground give way; houses assume various inclinations; walls crack and totter, and are only prevented from falling by huge unsightly buttresses. The preceding cut is from a sketch taken in Colebrooke Dale, situated on the upper course of the Severn, in the county of Shropshire. The Dale is enclosed by limestone rocks, covered by a succession of richly wooded knolls, presenting a succession of pictures, whose beauty is much obscured by smoke, and their tranquillity interrupted by the sound of the

EFFECTS OF MINING.

Digitized by Google

hammer and the roar of the furnace. At night-fall, the appearance of the Dale is peculiarly striking, being lit up by the flames of the blast furnaces of Horse Hey and Dawley, dissipating the darkness for miles around, by a flickering uncertain light, which is painful to the eye, and destructive of the repose which belongs to the night season.

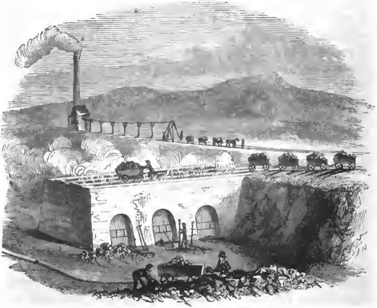
THEORY OF SMELTING.

In order to convert iron ore into metallic iron, regard must be had to the composition of the ore. In the rich hæmatite varieties it would be sufficient to raise them to a red heat, and pass a stream of hydrogen over them to effect their reduction, for in this case the oxygen of the ore would combine with the hydrogen, leaving metallic iron in a free state. The objection to this simple plan is, that the stony particles of the ore become so intimately mixed with the particles of iron, that these latter cannot combine or weld together. If the stony portion of the ore, or *gangue*, as it is called, be fused at a moderate heat, it might be got rid of by raising the ore to such a heat and beating it with a heavy hammer, when the gangue would escape like water from a sponge, while the particles of iron would weld together in a mass. If the gangue melted at a very high temperature, or were *refractory*, as it is called, it would fuse only at the temperature at which the iron, in contact with the fuel, became converted into *cast* instead of *malleable* iron, which would otherwise be obtained. Now the usual gangue of iron is clay or quartz, both of which do not fuse by the heat of a blast furnace. In order to get rid of them, however, they must be fused, and for this purpose one of two methods is adopted. In the case of a rich ore, from which malleable iron is to be produced, the ore is heated in contact with charcoal, when the gangue combines with a portion of the ore itself, which we suppose to be oxide of iron, and forms a compound which is very fusible, while the other portion of the iron is reduced, and can be separated by passing the spongy mass under a hammer, whereby the slag is expelled and the particles of iron are made to weld together. This process is wasteful both of iron and of fuel. It is still in use in places where wood is abundant for making charcoal, and the ore is rich, as in the Pyrenees, in Corsica, and some parts of Spain. It is known as the *Catalan* method, and is identical with the ancient process described at page 11. In the case of the poor ores, and with an impure fuel, when the object is to lose as little of the iron as possible, the gangue must be made fusible by a cheaper material than oxide of iron, for which purpose lime has been found to answer admirably. But as the compound of the gangue with lime is much less fusible than with iron, a very high temperature is required, and the iron produced is found in combination with carbon, forming what is called *crude* or *cast* iron, in a fluid state at the bottom of the receptacle prepared for it, with the gangue in the form of a slag resting upon it. Such is the *English* process by which by far the larger proportion of iron at present manufactured is produced; the iron ore with a proportion of carbonate of lime, as the flux, and coke or coal, as the fuel, is raised to a high temperature in a blast furnace, as will be described further on. The ironstone is, however, prepared for this operation by *roasting*, the effect of which is to expel water and carbonic acid, and to bring the ore to that porous state which is favourable for smelting. The clay ironstone of the coal measures, which is our chief source of iron, yields from 30 to 33 per cent. of pig iron, and loses from 25 to 30 parts in every hundred by roasting.

Digitized by Google

ROASTING THE ORE.

The first operation in the manufacture of iron is roasting the ore, which is done in kilns or furnaces, or in large heaps in the open air. When furnaces are employed, they are filled entirely with ironstone, except a stratum of coals at the bottom, the combustion of which produces the effect required. After the ironstone is sufficiently burnt, the register is shut up, the fire goes out, and when the furnace is cool enough, the ore is removed to the smelting-house.



ROASTING THE IRONSTONE IN KILNS.

The more common method, however, is to roast the ironstone in heaps, for which purpose a piece of ground is levelled, and covered with a layer of small pit coal, four, six, or eight inches thick. The pieces of ironstone, as near the same size as possible, are imbedded upon this to the height of from eighteen to twenty-four inches. The surface is again levelled by introducing small pieces of ironstone in the spaces left by the larger pieces. Upon this small coals are again cast, to the depth of two inches. Ironstone is then piled up, gradually narrowing to a wedge-shaped heap, and then the whole is covered over with small coal. The pile is lighted by applying burning coals to the ground stratum. The fire creeps slowly along, gradually inflaming the whole heap from the bottom to the top. When the coals are all burnt out, the pile gradually cools, and in eight or ten days it is fit for the furnace.

ROASTING THE IRONSTONE IN HEAPS.

COKING THE COAL.

In cold blast furnaces, or those in which cold air is used to excite combustion, the coal used in the reduction of the ironstone has to be converted into coke. Coking is performed upon a flat oblong or circular surface, called a *hearth;* this is prepared by beating it firmly, and puddling it over with clay. The coal is arranged on the hearth in pieces regularly inclining to each other, care being taken to place each piece on its sharpest angle, so that the smallest possible surface may touch the ground. By this means spaces are preserved for the admission of air necessary to ignite the coal, and room is left for the swelling of the various masses. In building the pile a number of vent holes are left, extending from the top to the bottom. In first igniting the heap, burning fuel is put into these vents, which are then stopped by small pieces of coal, to prevent the fire from ascending, and to force it to seek a passage by creeping along the bottom, where there is the freest access of air. When the fires of the different vents meet, the combustion gradually rises and bursts forth on all sides. Soon after the smoke has ceased, the fire is covered up with the dust and ashes of former burnings, beginning at the base, and gradually heaping it up to the top.

The quantity of coals coked in one hearth varies from forty to eighty or a hundred tons. The time required to produce good coke depends on the kind of coal used, and the state of the weather. The combustion may be complete, and the heap completely covered over, in from fifty to seventy hours; but it will not be cool enough for drawing under twelve or fourteen days. There is an enormous loss of weight in converting coal into coke. Mr. Mushet found that—

2,240 lbs. of free coals	yield 700 lbs. of coke,	making a loss of 1,540 lbs.
2,240 lbs. of splint and free coal, mixed	yield 840 lbs. of coke,	making a loss of 1,400 lbs.
2,240 lbs. of splint, slightly mixed	yield 1,000 lbs. of coke,	making a loss of 1,240 lbs.
2,240 lbs. of pure splint	yield 1,100 lbs. of coke,	making a loss of 1,140 lbs.

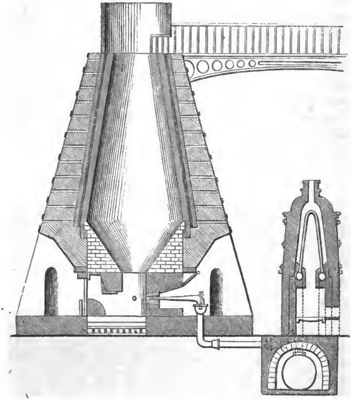
The appearance which these coking fires give to an iron district by night is very striking; and in

Wales, where the heaps are extended to a considerable length, the spectacle is described as being grand and imposing. "The long rows of flame produced by the burning of many hundred tons of coal, extending over a vast space of ground, and flickering in the wind; the black, grotesque figures of the cokers brandishing their long rakes, and partially visible through the thick lurid smoke, with the roaring of the blast and the noise of machinery, seem to realize the descriptions of Virgil or Dante, rather than any thing familiar to our experience in this habitable world."

SMELTING.

THE ironstone, the coke and the flux, being properly prepared, are brought to the blast furnace, which is the most important feature in an iron work, rising as it does to the height of from fifty to seventy feet, and lighting up the country around like a small volcano.

The external form of the smelting furnace is that of a truncated pyramid; it is built of strong masonry, with contrivances to prevent cracking by the expansion which takes place when it is brought to the state of intense heat necessary to smelt the ore. The interior of the furnace consists of five parts, which, reckoning from the bottom upwards, are as follows:—1. The *hearth*, which is composed of a single block of quartz grit about two feet square. 2. Upon this is erected what is sometimes called the *crucible*, which is a four-sided cavity, six feet and a half high, slightly enlarging upwards, so as to be two feet and a half square at the top. 3. The part above this, called the *boshes*, is in the form of a funnel or inverted cone, eight feet in perpendicular height, and twelve feet in diameter at the top; this is the widest part of the interior, and terminates (4.) the *cavity* of the furnace, which is conical in shape, and extends upwards to the height of thirty feet, the diameter at the top not being more than three feet; here it again enlarges into (5.) the *chimney*, which is about eight feet high

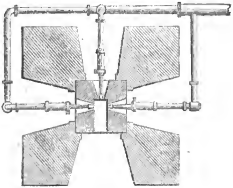


SECTION OF HOT BLAST FURNACE.

and sixteen in diameter at its mouth. This form at the upper part has been modified since the introduction of the hot blast, that given in the section being preferred.

About two feet above the hearth three openings are made in the sides of the crucible to admit the extremity of the blast pipes, through which air is forced into the furnace, and at the bottom of the crucible are openings through which the scoriæ and melted metal are from time to time discharged.

The cavity of the furnace receives a double lining of fire-bricks made expressly for the purpose. A space three inches broad is left between the two



ARRANGEMENT OF BLAST PIPES.

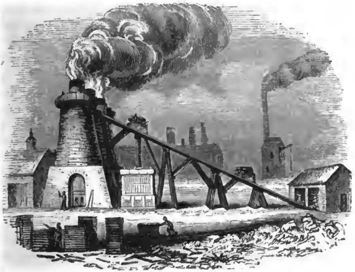
linings, which is filled with moist loamy sand. This space is allowed for any expansion which might take place in consequence of the swelling of the materials when the furnace is at work.

The above are the dimensions of a moderately sized furnace. The largest furnaces probably in the world are those of South Wales, the diameter at the boshes or widest part being in some cases from 15 to 18 feet, and having a capacity equal to 7,000 cubical feet. Such a furnace, when at work, will contain at least 150 tons of ignited materials. In Staffordshire, Shropshire, and other parts of England, a furnace seldom exceeds 13 or 14 feet diameter at the boshes.

When a new furnace has been erected, considerable care is required in raising it to the temperature necessary for smelting iron. A temporary fireplace is first erected at the lower part, to which the whole cavity of the furnace is made to act as a chimney; so that when the fire is lighted the draught is violent, and much heat is carried up. This fire is kept burning for about three weeks, at the end of which time the furnace is sufficiently dry to receive a charge of coke; the temporary fire-place is removed, and other preparations made for the purpose. A quantity of ignited coke is thrown in, and this is gradually increased until the whole cavity is filled. The quantity required by a furnace of the dimensions given above will be about 99,000 lbs.; the splint coal for which would weigh 198,000 lbs. "When we reflect," says Mr. Mushet, "that this vast body of ignited matter is replaced every third day when the furnace is properly at work, a notion may be formed of the immense quantity of materials required, as also the consequent industry exerted to supply one or more furnaces for the space of one year."

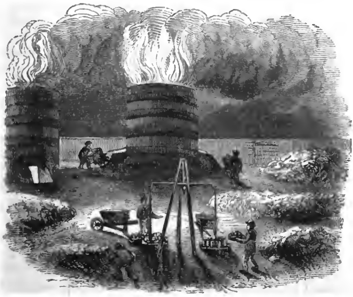
All the materials are conveyed in wheel-barrows, and thrown into the furnace at its mouth or chimney. When there is a regular incline from the coke-yard or kilns to the furnaces, the loaded barrow is wheeled directly to the furnace-top; but in a flat country the barrows are arranged on stages, which are supported in a horizontal position, and drawn up an inclined plane as shown in the annexed cut, which represents some furnaces near Hanley, in Staffordshire, which were visited by the writer. At the top of the inclined plane is a gallery sufficiently wide for wheeling the barrows round to the three mouths with which each furnace is provided, and into these a man called the *filler* throws the contents of each barrow. At the furnaces at Horse Hey there is a regular ascent from the coke-yard to the mouths of the furnace, and small carriages moving on a railroad bring up constant supplies of coke or coal, ironstone and limestone, which are weighed in certain proportions and conveyed in barrows to the mouths of the furnaces, as shown in the following cut.

When the furnace has been sufficiently heated by coke, proportionate *charges* of coke, ironstone, and blast furnace cinders are added. At first the ironstone bears only a small proportion to the weight of the coke, but this is afterwards increased to the full burden. The filling is continued regularly, and when



BLAST FURNACES.

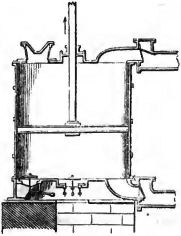
the top of the furnace has acquired a considerable degree of heat, the blast is introduced.



MOUTHS OF BLAST FURNACES.

Digitized by Google

The blowing machines vary considerably in construction at different works; a very common arrangement is to have a cylinder at the end of the beam of a steam-engine of twenty or thirty horse-power, closed at both ends, with a piston moving throughout its length. Towards the top and bottom of this cylinder are orifices covered with valves, opening inside, and closing by their own weight. When the piston is moving downwards and expelling the air below it out of the cylinder, a fresh supply of air rushes in through the upper valve, so that by the time the piston is ready to make its up-stroke the cylinder is again filled. During the up-stroke all the air above the piston is expelled, and the lower valve opens, and air rushes in to fill the cylinder below the piston. It is evident, however, that this action would not produce a regular blast: the air is, therefore, received into a large metal box or globe, and the elasticity which it here acquires by compression causes it to issue in a nearly equable stream. This vessel is furnished with a safety-valve, by which the pressure of the air is regulated, the pressure being

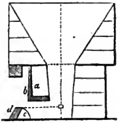


SECTION OF BLOWING APPARATUS.

made to vary according to the nature of the fuel and the season of the year. In summer, when it is more rare, it is expelled under greater pressure. The limits are from $1\frac{1}{2}$ lbs. to $3\frac{1}{2}$ lbs. on the inch, in addition to the average pressure of the air, which is $14\frac{3}{4}$ lbs. on the square inch of surface. The orifices, or nose pipes, through which the air issues, also vary with the nature of the coke and the ore, from $2\frac{5}{10}$ to $2\frac{8}{10}$ inches in diameter.

We are so much accustomed to consider air as having little or no weight, that the fact may perhaps excite surprise that the weight of the air sent into the furnace in the twenty-four hours is at least four times as much as that of the charge. In a cold-blast furnace near Glasgow, a few years ago, the volume of air thrown in, when reduced to atmospheric pressure, was estimated at 6,292 cubic feet per minute, the weight of which in 24 hours would be 6,192 *hundred weight*, while the whole weight of the charges of coke, ore, and limestone during the same period was no more than $66\frac{1}{2}$ *cwt.*, so that in this case the weight of air was more than nine times and a quarter that of the charges. This, however, was an extraordinary case; but by another calculation it appears, that an ordinary cold-blast furnace consumes as much air as is required for the respiration of 200,000 persons.

As we are tracing the operations for a new furnace, it is necessary here to remark, that before admitting the blast certain preparations are necessary. The dam-stone *c* is laid in its place and firmly imbedded in fire-clay; the dam-plate *d* is again imbedded on this with the same cement, and the same inclination is given to it. On the top of this plate is a slight depression curved outwards, for allowing the scoria to flow off in a connected stream as it tends to sur-



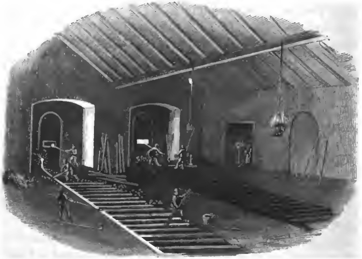
mount the level of the dam. From this notch to the level of the floor, a declivity of brickwork is erected, down which the scoria flows. The opening between the dam and the side walls of the furnace, called the *fauld*, is stopped up with sand, and the furnace bottom is covered with powdered lime or charcoal dust. Ignited coke is then allowed to fall down, and is brought forward with iron bars nearly to a level with the dam. The tuyere hole is opened and lined with a soft mixture of fire-clay and loam. The blast is first introduced through a small discharge pipe, which is afterwards increased in size. In about two hours after blowing, a considerable quantity of lava will be accumulated, which is admitted to all parts of the hearth, and soon thoroughly heats and glazes the surfaces of the fire-stone. It then rises to a level with the notch in the dam-plate, and flows over. When the metal has risen nearly to a level with the dam, it is let out by cutting away the hardened loam of the fauld, and conveyed by a channel made in sand in front of the furnace to its proper destination, which will be further noticed presently.

In six days from the commencement of blowing, the furnace will have wrought itself clear, and will have acquired capacity sufficient to contain from 5,000 to 7,000 lbs. weight of iron. At this period the charge will be in the following proportions:—400 lbs. of coke, 336 lbs. of ironstone, and 100 lbs. of limestone. This charge is thrown into the furnace every hour.

The action of the coke, the ironstone, and the limestone upon each other in the furnace has been already briefly explained (see page 31). They form at the bottom of the furnace two liquid products, one of which is a glass composed of the limestone in combination with the earthy impurities of the ore, which when drawn off and left to cool forms solid *scoriæ*, *slag* or *cinder;* and the other a compound of the carbon of the fuel and the metal, forming a *car-*

buret of iron. As the materials gradually descend from the top to the bottom of the furnace, the ore is undergoing cementation during several hours in contact with the burning fuel, and is almost saturated with carbon when it reaches the bottom of the boshes, or hottest part of the furnace. Here it is that the limestone-flux and the earthy impurities of the coke and ore run down into a slag; the iron also is melted, loses a portion of its carbon, and acquires oxygen from the blast. The fluid mass soon sinks to the bottom of the furnace beyond the influence of the blast,—the iron being the heaviest occupies the lowest place, and the covering of scoriæ protects it from further loss of carbon. As the melted matter accumulates, the slag is allowed to flow out, as before noticed, and the iron is drawn off at intervals every eight or twelve hours, according to circumstances. This work is continued with double sets of attendants, day and night without intermission, for two or three years; for if the furnace were allowed to cool, the contents might become solid and the furnace be ruined. The writer, however, has peculiar satisfaction in learning that arrangements have been made at some works for not casting on Sundays, so that nothing more is required than the attendance of a single workman to keep the furnaces supplied with fuel.

Drawing off the iron, or *casting*, as it is called, is a beautiful and striking spectacle. The shed in front of each furnace is covered with sand to the depth of about ten or twelve inches; previous to each *cast* a channel called the *sow* is formed in the sand, extending some forty or fifty feet from the furnace; branching off from the sow at right angles a number of smaller channels, called *pigs*, are formed by burying a number of bars of wood of the required size, on the removal of which the pig-moulds are left sharp and distinct. The hole in the bottom of the hearth, which was stopped with a mixture of sand and clay, is tapped, and the molten stream flows out sparkling and bright, the light and heat becoming more and more intense as it rolls on and increases in volume. In order to make the metal flow regularly into the side channels, it is necessary here and there to interrupt the progress of the stream, which is done by a long piece of wood, as the metal does not continue sufficiently fluid to fill them up equally, but by this method the pigs are all perfectly formed. When the metal is set, the pigs are broken off from the sow, and the latter is also broken to pieces with a large sledge hammer.



CASTING.

Six different kinds of pig iron are distinguished by the manufacturer. The first three, named No. 1, No. 2, and No. 3, are considered as foundry metal; they contain carbon in different degrees, but all of them in a higher degree than those selected for making bar or malleable iron. No. 1 is saturated with carbon, the effect of which is to render the iron soft, and very fluid when melted, so that it will adapt itself perfectly to the shape of the mould, and is hence used for small and ornamental castings. It is also so soft as to yield readily to the chisel. No. 2 contains less carbon than No. 1; it is not so soft when cold, nor so fluid when melted; but, being harder and stronger, is preferred for those parts of machinery which require strength and durability. The quantity of carbon contained in these two sorts renders them unfit for being manufactured into bars; but No. 3, or *dark grey iron*, containing less carbon than No. 1 or No. 2, can be used either for the forge or for the foundry. It is much used for heavy castings, such as tram-plates, heavy shafts, wheels, cylinders of steam-engines, &c. The next quality is called *bright* iron, from its being of a lighter colour and brighter lustre than the foregoing varieties. It is used for large castings, but is not sufficiently fluid for fine work. A fifth variety is *mottled* iron, the fracture of which is *mottled* with grey and white. It is too thick and brittle for the foundry, and its use is therefore confined to the forge. The last variety is called *white* iron, from its silvery white colour. It is quite unfit for casting, on account of its thickness and extreme brittleness. It contains a smaller proportion of carbon than any other sort of pig iron.

The different kinds of iron present different phenomena in coming out of the furnace; these have been well described by Mr. Mushet. He says:

"When fine, (No. 1) or supercarbonated, crude iron is run from the furnace, the stream of metal, as it issues from the fauld, throws off an infinite number of brilliant sparkles of carbon. The surface is covered with a fluid pellicle of carburet of iron [plumbago], which as it flows rears itself up in the most delicate folds. At first the fluid metal appears like a dense ponderous stream, but as the collateral moulds become filled, it exhibits a general rapid motion from the surface of the pigs to the centre of many points; millions of the finest undulations move upon each mould, displaying the greatest nicety and rapidity of movement, conjoined with an uncommonly beautiful variegation of colour, which language is inadequate justly to describe. Such metal in quantity will remain fluid for twenty minutes after it is run from the furnace, and when cold will have its surface covered with the beautiful carburet of iron, already mentioned, of an uncommonly rich and brilliant appearance."

Very different is the appearance of the inferior iron, No. 4, when issuing from the blast furnace. From all parts of the fluid surface are thrown off a vast number of metallic sparks, arising from a cause different to that exerted in the former instance. The absence of carbon renders the metal subject to the combination of oxygen as soon as it comes into contact with atmospheric air. Small spherules of iron are ejected from all parts of the surface, to the height of two or three feet, when they inflame and separate with a slight hissing explosion into a great many minute particles of brilliant fire. These particles consist of oxide of iron. "The surface of oxygenated iron, when running, is covered with waving flakes of an obscure smoky flame, accompanied with a hissing noise; forming a wonderful contrast with the fine rich covering of plumbago in the other state of the metal, occasionally parting and exhibiting the iron in a state of the greatest apparent purity, agitated in numberless minute fibres, from the abundance of carbon united with the metal."

As the oxygenated iron cools, its upper surface becomes covered with a scale of blue oxide, which being removed, a number of deep pits are presented. "This iron in fusion stands less convex than carbonated iron merely because it is less susceptible of a state of extreme division; and, indeed, it seems a principle in all metallic fluids, that they are convex in proportion to the quantity of carbon with which they are saturated." The appearances of No. 2 and No. 3 in a state of fusion present some of the appearances of both No. 1 and No. 4.

The quality of the metal can also be judged of, before it is run from the furnace, by the colour and form of the scoriæ, the colour of the crust upon the working bars, and the quantity of carburet attached to it. That cinder which indicates the presence of carbonated iron in the hearth of the furnace forms itself into circular compact streams, which become consolidated and inserted into each other; these are in length from three to nine feet. "Their colour, when the iron approaches the first quality, is a beautiful variegation of white and blue enamel, forming a wild profusion of the elements of every known figure; the blues are lighter or darker according to the quantity of the metal and the action of the external air while cooling. When the quality of the pig iron is sparingly carbonated, the blue colour is less vivid, less delicate, and the external surface rougher and more sullied with a mixture of colour." The cinder emitted from the furnace when No. 3 iron is produced, assumes a long zigzag form. "Its tenacity is so great, that if, while fluid, a small iron hook be inserted into it at a certain degree of heat, and then drawn from it with a quick but steady motion, 20 to 30 yards of fine glass thread may be formed with ease. When by accident a quantity of this lava runs back upon the discharging pipe, it is upon the return of the blast impelled with such velocity as to be blown into minute delicate fibres, smaller than the most ductile wire. At first they float upon the air like wool, and when at rest, very much resemble that substance."

The cinder frequently crystallizes in cooling: cellular masses form among it, which on being opened are sometimes found full of perfectly crystallized forms.

Digitized by Google

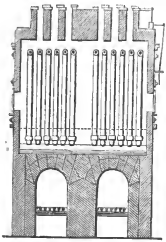
THE HOT BLAST.

It had long been the opinion of practical men that the colder the blast the better was the iron produced, and this opinion seemed to be confirmed by the fact that blast furnaces did their work better and produced more iron in winter than in summer. Considerable surprise was therefore felt in the year 1828 when the discovery was announced, that by using a *hot* instead of a *cold* blast, a great saving of fuel could be effected, and a much larger quantity of iron produced. This discovery was made by Mr. Neilson, manager of the Glasgow Gas Works, who has himself related the circumstances which led to it.

"In 1824, an ironmaker asked Mr. Neilson if he thought it possible to purify the air blown into blast furnaces, in a manner similar to that in which coal gas is purified; and from this conversation Mr. Neilson perceived that he imagined the presence of sulphur in the air to be the cause of blast furnaces working irregularly, and making bad iron in the summer months. Subsequently to this conversation, which had in some measure directed his thoughts to the subject of blast furnaces, he received information that one of the Muirkirk iron furnaces, situated at a considerable distance from the engines, did not work so well as the others; which led him to conjecture that the friction of the air, in passing along the pipe, prevented an equal volume of the air getting to the distant furnace, with that which reached to the one situated close by the engine; and he at once came to the conclusion, that by heating the air at the distant furnace, he should increase its volume in the ratio of the known law according to which airs and gases expand. Thus, if 1,000 cubic feet, say at 50° Fahr., were pressed by the engine in a given time, and heated to 600° Fahr., it would be increased in volume to 21,044; and so on for every thousand feet that would be blown into the furnace. In prosecuting the experiments which this idea suggested, circumstances however convinced him, that heating the air introduced for supporting combustion into air-furnaces, would materially increase its efficacy in this respect; and with the view of putting his suspicions on this point to the test, he instituted the following experiments:—to the nozzle of a pair of common smith's bellows he attached a cast-iron vessel, heated from beneath in the manner of a retort for generating gas; and to this vessel the blow-pipe by which the forge or furnace was blown was also attached. The air from the bellows having thus to pass through the heated vessel above mentioned, was consequently heated to a high temperature before it entered the forge fire, and the result produced in increasing the heat in the furnace was far beyond his expectation; whilst it made apparent the fallacy of the generally-received theory, that the coldness of the air of the atmosphere in the winter months was the cause of the best iron being then produced. But in overthrowing the old theory, he had also established new principles and facts in the process of iron-making, and by the advice and assistance of his friends, he applied for and obtained a patent as the reward of his discovery and improvement."

The method of heating the air was not made the subject of the patent. The air-heating vessels first used were in the form of a round, a square, or a cylindrical box; they were next elongated, and by a further improvement were divided into parts; but the best form, and that which is now generally used, is a congeries of tubes, whereby the greatest extent of heating surface is obtained. The following is a lateral section of the last-named apparatus, in which the air can be raised to 600°, the melting point of lead, at which temperature the greatest effect is produced, and is determined by holding a piece of lead over an orifice in the blast pipe.

The hot blast was soon adopted in Scotland, and more slowly in England. The charge made by the patentees for a licence to use the invention was one shilling for each ton of iron produced by it; and it has been calculated that on the expiration of the patent in 1842 the patentees had received no less a sum than 300,000*l.*



SECTION OF HOT BLAST APPARATUS.

The value of the hot blast will be at once appreciated from the following facts: (1) coal can be used in the blast furnace instead of or mixed with coke, (2) a much less quantity of fuel is required, and (3) less limestone is needed as flux. It has been calculated that on every ton of iron produced by the hot blast, there is a saving of 1*l.* 12*s.* 6*d.*; viz. five tons of coal at 5*s.* 6*d.* per ton; half a ton of limestone at 4*s.* per ton, and 3*s.* saved in wages by not coking the coal.

The great saving of fuel in the furnace by the use of the hot blast will be understood by considering for a moment the nature of combustion under ordinary circumstances. A combustible body, such as paper, wood, coal, and a supporter of combustion, such as the oxygen of the atmosphere, show no tendency to unite at the ordinary temperature of the air; but if either the air or the combustible body be raised to a high temperature, a union between the two takes place with a rapidity proportioned to the temperature, and also with the production of heat and light. The air which feeds an ordinary fire must be raised by the burning fuel to the combining temperature before combustion can take place, but if by any contrivance a high temperature be imparted to the air before it reaches the fire, part of the work of the burning fuel is already performed, and it will not only burn longer, but will give out a greater heat, because it has not to expend so much of its force in raising the air necessary to feed it to the proper temperature.

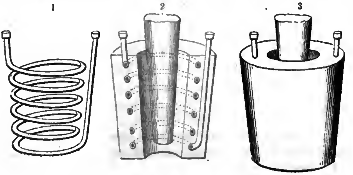
In the blast furnace a great and long-sustained heat is necessary to effect the reduction of the iron. Now it must be obvious under the cold blast method, that one portion of the fuel in the furnace is employed in raising the air to the necessary temperature, thereby rendering the other portion less efficient, and tending to depress the temperature of the whole contents of the furnace. Besides this, there is another drawback. When compressed air escapes from pressure, its temperature is many degrees below that of the external air. Mr. Mushet states, as the result of actual experiment, that while the heat of the outer air was from 60° to 70° Fahr., the temperature of the blast as shown by a thermometer held in it, was as low as 38°. It is, therefore, easy to perceive that a very large proportion of the fuel of the furnace must be expended in raising the temperature of the blast to the point of combustion: but by the hot blast the whole of the fuel is effective in doing the proper work of the furnace, in maintaining a higher temperature than could otherwise be produced, and consequently economising the fuel, and affording more iron in less time. Mr. Mushet thinks, that previous to the introduction of the hot blast, nearly one half the quantity of the fuel introduced into the furnace was expended in preparing the air for combustion. By means of the hot blast the air is rapidly and entirely decomposed, "an intense temperature is excited locally, into which the fusing matters precipitate themselves, and where separation is effected under a degree of heat not formerly known to exist in the blast furnace. The whole of the blast being decomposed between the tuyeres and the boshes, the upper part of the furnace becomes converted into a cone of cementation, wherein the important but progressive processes of deoxydation and carbonization are carried on and perfected in the absence of oxygen, and in a more certain state of preparation than is effected under the cold blast system."

Another advantage of the hot blast is that ores previously unfitted for the manufacture of foundry iron can now be smelted. Anthracite, or stone coal, which formerly could not be used in the furnace, is now used in the raw state. The pig iron is also of better quality; for with the cold blast it is necessary that a certain quantity of earthy matter be present in the furnace, to form cinder for the protection of the iron, and to prevent the furnace from throwing off black cinder, technically called *scouring ;* this is no longer necessary, because the iron when it flows from a hot blast furnace has a much higher temperature than under the cold blast, and it is stated that oxygen does not readily unite with iron at a very high temperature. "That such intense temperature is communicated to the pig iron made with hot blast, is sufficiently obvious at casting time, when the highly convex stream of metal is seen rolling from the furnace, active with external motion, and disparting itself in millions of delicate yet distinct undulations as the current recedes from the furnace to occupy and fill its destined channels in the sand bed. An eye accustomed to view appearances of this sort will at once, as soon as the iron has left the furnace, perceive a glow upon its surface beyond what is commonly called a white heat, a liquidity, carrying with it a slight tinge of azure."

One defect of hot blast iron is said to be a slight deterioration in strength, which arises probably from the high temperature at which it is finally separated from its ores, communicating, by a new and more perfect crystallization, a weaker arrangement of parts. It has also been suggested that silica may be reduced with the ore, and its metallic base, silicium or silicon, uniting with the iron, imparts to it a certain amount of brittleness.

The increased quantity of iron produced under the hot blast, produces, of course, an increased quantity of vitreous matter or cinder, which no longer flows in streams forming columns of from three to nine feet in length, but in liquid torrents of from fifteen to twenty feet in length. At some furnaces where a powerful blast is used, accompanied with a proportionate flow of cinder, it is at once run into wagons made of strong sheet iron or boiler plate, and taken away to the cinder tip, over which it is discharged in solid masses, moulded to the shape of the wagon. By this contrivance a great saving of labour is effected, the clearing away of the cinder under the old method being the most laborious part of the attendance on a blast furnace.

The increased heat caused by the use of the hot blast rendered some contrivance necessary to protect the nozzle of the air pipe as it entered the furnace. The following ingenious method was adopted. Within the sides of the iron tuyere through which the nozzle passes, is introduced a spiral pipe, in which a stream of water is constantly playing. The tuyere is thus kept comparatively cool, forming an effectual protection to the nozzle of the air pipe. The first of

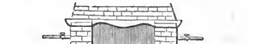


WATER APPARATUS FOR NOZZLE OF TUYERE.

Digitized by Google

the foregoing figures shows the form of the spiral tube before being cast into the metal of the tuyere; the second figure is a section of the tuyere or tue-iron, showing the spiral tubing enclosed in cast iron. The nozzle of the blast pipe is also shown introduced into the tuyere, the surrounding space being afterwards filled with fire clay. The third figure shows the tuyere ready for putting into the furnace. "Without the cooling effects of water circulating with rapidity on the confines of the fire, and frequently penetrating to some distance within it, there is no substance with which we are acquainted that could for any length of time have resisted the action of so intensely heated a body of fire."

The following section shows the arrangement of the



SECTION OF LOWER PART OF FURNACE.

lower part of a *finery* furnace, next to be described, with two of the tuyeres, water apparatus, &c.

REFINING.

ALL the varieties of pig iron contain certain impurities, which render them brittle under the hammer, and therefore quite unfit for the numerous purposes of the forge. These impurities consist chiefly of carbon and silicium (a good deal of the latter being derived from the sand which adheres to the pigs in the casting), and minute portions of sulphur and phosphorus. The carbon and silicium are removed by exposing the pig iron to a high temperature, under the influence of a blast of air. The effect of this treatment is to convert the iron into an oxide, and the carbon of the iron reacts upon this oxide, converting it into the metallic state, and passing off with the oxygen in the form of carbonic oxide gas. In a similar manner the silicium is converted into silicic acid, which, combining with a portion of the oxide of iron, forms a fusible silicate of iron. These actions and reactions are continued in the processes of *refining* and *puddling*, until the whole of the iron is converted into a spongy mass of malleable iron and fusible slag; which being submitted to the blows of a heavy hammer, the silicates are pressed out. The removal of the sulphur and the phosphorus is more difficult, and it is better to get rid of them previous to smelting, by carefully roasting the ore with the addition of carbonate of lime, which forms a sulphuret and a phosphuret of calcium, which escapes with the slags.

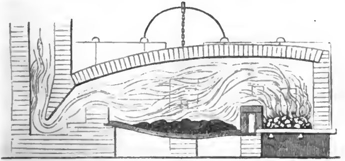
Pig iron is refined in small low furnaces called *fineries*. The bottom of the hearth of a finery is about three feet square, and is made of fire-brick; the front, back, and sides, are of cast iron, and made hollow, so as to allow water to stream through them, to prevent the intense heat of the fire from burning them away. Near the top of the hearth are three holes for the blast pipes. In what are called *single fires* the blast is applied on one side only; in *double fires* on both sides, the latter being of much larger capacity than the former. The tuyeres are protected in a similar manner to those in the blast furnace. The finery has iron doors at the back, but the front is open, and pours forth such torrents of heat that it is impossible for any but those accustomed to it to approach very near. A low chimney surmounts the furnace, which altogether does not exceed about twenty feet in height. In front of the fire is a shed for the protection of the workman. The refiner selects his materials according to the quality of the iron required, the best quality being made from the dark grey pig, No. 3, and inferior sorts from bright, mottled, and white. The proper weight of pigs is put into the refinery by opening the iron doors at the back, and the fire is kept well supplied with coke, and frequently stirred up to equalize the heat in all parts of the hearth; under the influence of the powerful blast (the pressure of which is about the same as at the blast furnace) the pigs are soon melted, and the operation of refining goes on. A portion of the carbon of the pig unites with an equivalent portion of the oxygen of the blast, and is driven off in the form of carbonic acid. In about two hours the metal is in a proper state to run out. A hole at the bottom of the hearth in front is tapped, and the metal flows out along a short channel into an oblong flat mould of stout cast iron, about twenty feet long by two feet broad, placed over an iron cistern, through which water flows, which serves to cool the fluid metal, and to prevent the mould from cracking. A quantity of cinder which flows out with the metal rises to the surface, and is run off through a hole made in the sand which forms one of the short sides of the mould. As soon as the metal is set, this sand is removed, and the plate is turned out of the mould into a trough of water, which *quenches* it, and makes it very hard, brittle, and sonorous. Its fracture presents a bluish or a silvery white colour, according to its hardness.

The finery furnace is worked day and night (Sundays excepted), with a double set of men. The mould of metal, weighing about a ton, is run out every two hours; so that the quantity of refined iron produced from a double furnace in one week will be about sixty or seventy tons. The pig iron suffers a loss of about ten per cent. in refining, but this varies considerably according to circumstances.

PUDDLING.

The process of refining does not separate carbon and silicium from the pig iron sufficiently for the purposes of the forge. The plate of iron from the finery mould is therefore broken up, and weighed out into portions of about four hundred-weight each, called *heats* of metal, and consigned to the puddling furnace, where the metal is still further decarbonized.

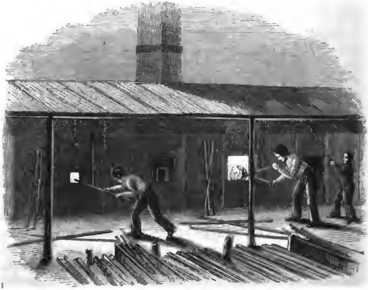
The puddling furnace consists of a fire, the flame of which, by a peculiar construction of the brickwork, is *reverberated* or reflected down upon the iron situated in the space between the fire and the chimney, as shown in the following section. The bottom of the furnace is formed of a thick cast iron plate, protected by a coating of the oxide or cinder formed in puddling. The chimney is about thirty feet high, and has a damper at the top, by which the draft is regulated. This can be made so strong as to carry the flame out at the top of the stack in contact with the damper. The iron is put in and taken out of the furnace by a large square opening, which, except on such occasions, is kept covered with an iron door, made to slide up and down by means of a lever and chain. At the bottom of this door is a small hole, through which the puddler introduces his tools, and inspects his work. The fire is fed by a small hole at



SECTION OF PUDDLING FURNACE.

the side called the *stoke-hole*, which is usually kept stopped with a piece of coal.

The metal is put into the furnace with an instrument shaped somewhat like a baker's wooden shovel, the door is then carefully closed, and all allowed to remain quiet for about half an hour, when it begins to melt. The puddler then introduces a bar, turned at the end like a hoe, and arranges the pieces of melting metal in such a manner that all may be equally exposed to the action of the flame, and melt as nearly as possible at the same time. If this is not done, the portions which melt first burn away and are lost. When the whole is melted, he stirs it up in all directions, so as to expose every part in its turn to the action of the flame, and occasionally throws small scoopfuls of water upon it. The tool, of course, soon becomes red hot, and must be changed for a cold one, the hot one being thrown into a trough of water as soon as it is withdrawn. The liquid metal heaves and



PUDDLING.

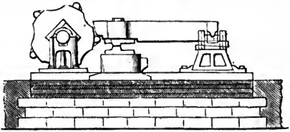
boils, and is covered with bubbles, which, as they burst, give out little jets of white or blue flame. After a time this boiling ceases; the mass gradually becomes thicker, and as it is turned over it presents a curdy appearance, the small points and corners glowing with a white heat, while the mass itself looks cooler. In this state the workman says it is "coming round to nature." He continues to stir it vigorously until it becomes tenacious enough to stick together and form into lumps. He then divides it into four or five separate portions, made as round and compact as possible; this is called "balling up," and the balls are called "puddler's balls;" this finishes the operation of puddling. A puddler works about six or seven heats in the course of twelve hours.

SHINGLING.

The balls formed by the puddler are taken out one by one by means of a pair of tongs, as shown in the cut at page 58, the puddler's assistant holding up the door of the furnace, and letting it drop as soon as a ball is taken out, in order to economise the heat of the furnace. It is dragged along the floor by means of the tongs to the shingling hammer, where it receives a few blows, the effect of which is to make the ball more solid, and to reduce it to an oblong shape, better fitted for the next operation of rolling. It also forces out a portion of the liquid cinder, which is separated from the pure iron in puddling.

The shingling hammer weighs about four tons, and consists of a ponderous cast iron shaft or *helve*, through the head of which the hammer is inserted. The hammer is lifted by means of a *cam*, revolving under the tennant or nose of the helve, consisting of three or four chilled iron levers turning upon an axis, so that as they act in succession upon a projection under the helve, the hammer is made to rise and fall as required.

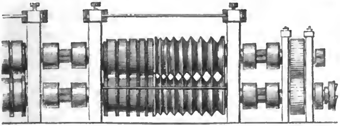
As soon as the ball of iron is under the hammer, the shingler throws aside the tongs, and receives from his assistant an iron bar which has been heating for the purpose in the stoke-hole of the puddling furnace, and placing one end of this upon the bloom, the hammer forces it into the semi-fluid mass, and with this the bloom can be turned over and over so as to receive the strokes of the hammer to advantage. From ten to twenty blows are generally sufficient to produce the effect required. The bloom hisses, bubbles, and flames under the operation, and sparks fly off and streams of cinder gush out with considerable force in all directions, making it necessary for the shingler to wear very thick leather leggings and apron. If the puddling has been properly done, the bloom is brought to a firm and tenacious mass; but if the puddling has been neglected, some portions of the bloom will be harder than the rest, and will not adhere well together. Such a bloom is termed a *shadrach*, and is returned to the puddler, who is fined for his neglect.



SHINGLING HAMMER.

ROLLING.

The bloom being properly shingled is handed over while still at a bright red heat to the roller, who passes it quickly through the *puddle-rolls*, using first the largest hole and then the smaller ones in succession. A lad on the opposite side, called the *catcher*, receives the bloom with a pair of tongs every time it goes through the holes, and passes it over the rolls to the roller.* When it has gone through all the holes of the first pair of rolls it is passed through the different grooves of the second pair, where it is reduced to a more accurate form and to the dimensions required. In passing between the rolls a further portion of cinder is driven off, the greater part of which falls into a hollow space beneath.



PUDDLE BALL ROLLS.

The puddler is paid according to the weight of rough bars produced; the yield of each puddling furnace is therefore arranged in a separate division, as shown in the cut at page 58. 22 cwt. is about the quantity of metal required to make a ton of rough bars.

The shingling hammer, the rolls, and other machinery of the forge, are of very massive construction. A firm foundation is formed by heavy cast-iron plates imbedded in masonry underground, where also the uprights or sides of the rolls are securely fixed, and a number of wheels and shafts arranged for giving the required speed to the different sets of rolls. Hence the weight of machinery underground is almost equal to that above, and renders it difficult to trace the connexion of the different parts of the machinery with the steam-engine.

The rolls are made of bright iron of the hardest quality, and are cast solid. They are then turned to the required shape with steel tools, the motion being very slow, to diminish the heat excited by the friction, or they would otherwise soon lose their edge. In mounting the rolls in the forge brass bearings are provided, as also for the axles of wheels and the ends of shafts, the friction between two different metals being much less than between two pieces of the same metal. The points of friction are also kept well oiled, and perfectly cool by streams of water.

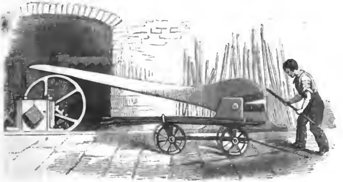
---

* See Frontispiece.

After the iron has passed through the first two sets of rolls the operations at the forge are completed. It has been brought to the state of rough bar, very different from the pig iron used to produce it. This was very hard, very brittle, and readily fusible; it is now a long slender bar of soft, tough, malleable iron, fusing with difficulty.

The change which has thus been produced of converting cast or pig iron into bar or malleable iron has been attained at the cost of much labour and fuel. A few years ago it occurred to Mr. Bessemer that the operations of refining and puddling might be got rid of, and the cast iron, as it was drawn out of the blast furnace, be at once converted into malleable iron by directing upon it a blast of atmospheric air. It was supposed that the oxygen of the air would combine with the carbon of the iron, and remove it in the gaseous form, while the silicon would rise to the surface and boil off in the form of a slag. The writer witnessed a trial experiment made in Mr. Bessemer's yard, and the result certainly seemed to justify the inventor's anticipation, of ordinary pig being converted into malleable iron. We are not however aware what is the loss in this operation; but we should imagine it to be large, from the circumstance that in the intense chemical action (which has a beautiful and impressive effect towards the close of the operation) a large quantity of iron was burnt, and dissipated in the form of vapour. The remark of an iron-master to the writer, that "iron is a very expensive fuel to burn," is probably the reason why the process is not more generally adopted.

The bar iron is not yet fit for the market; its surface is scaly and uneven; its edges are rough and imperfect, and it is too unsound in texture for the use of the smith: the bars are therefore further purified at the *mill*, for which purpose they are cut into lengths by a strong pair of shears. The rough bars are generally two, three, or four inches in width, and half an inch or rather more in thickness; and the lengths into which they are cut are of course adapted to the size of the finished bar. Equal lengths are made up into piles, each consisting of several pieces placed evenly one upon another. These piles are then placed in a balling or heating furnace, which is a reverberatory furnace, similar in construction and shape to the puddling furnace; but instead of having a coating of oxide of iron or of cinder at the bottom, it is kept covered with loose sand.



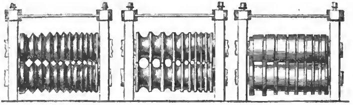
SHEARS.

It is of importance that the piles be formed evenly, and with no projecting or ragged edges, because when placed in the furnace these become heated first, and begin to burn away before the rest of the pile is hot enough for rolling. Considerable care and experience are required to decide when the piles have attained the proper welding heat, and also to prevent those from burning which are ready to be taken out; but if the roller is not quite ready for

Digitized by Google

them, a handful of sand thrown over the pile is the usual expedient to prevent burning. For small bars as many as twelve or sixteen piles are put into the furnace; for large ones not more than four or five are put in. The cinder separates itself from the iron while in the balling furnace; first appearing as a sort of glaze over the pile, and then flowing away down the bottom of the furnace, which is made with a slope for the purpose of carrying off the cinder.

Each pile, as soon as it is taken out of the furnace, is passed between rollers, which are of great variety, according to the kind of bar required, such as round, square, or flat; and there are also three sizes of each; the largest being about 14 to 16 inches in diameter; the middle 10, and the small rolls 7. The large rolls move at the rate of about 70 revolutions in a minute, the middle-sized rolls 140, and the small ones 230 or 240. *Roughing rolls* are first used to bring the bar nearly to the shape required; it is then passed through the *finishing rolls*, which complete the work. In passing through the several grooves of each roll the pile gradually diminishes in size, and the pieces composing it become firmly welded together, and at the same time elongated into a bar, any remaining portion of cinder being also squeezed out. The roller and his assistant do their work as quickly as possible, that the bar may not be too cool to pass through the grooves, for if such be the case it must be heated again before it can be finished.


FINISHING, OR BAR ROLLS.

The separate pieces which compose the pile produce a fibre in the bar, which adds greatly to its strength and toughness. In good iron this fibre is always perceptible, however perfect the weld. In rolling flat bars the layers of the pile are kept horizontal, in order that the fibres may be as straight and parallel as possible. The experienced blacksmith, in working up his bars, always attends to the direction of the fibre, because by doing so he can make the most of his iron, and increase the strength and toughness of the articles produced.

In rolling iron there are always certain little irregularities in the work produced, which have been noticed by a practical writer in the following terms:—"However true the rolls may be formed there will always be a little space between them, which will prevent the angles of the square bar formed at their junction, from being so perfect as those formed in the moulding of the roll itself. When the bar, therefore, has been reduced to the required size, it is again put through the same groove, turning it so that the angles shall be changed, those formed before at the sides being now at the top and bottom, by which means they are sharpened and corrected. Round iron also, being formed between the two semicircular grooves of the two rolls, is liable to the same imperfection unless it is passed several times through the last hole; and even this repetition does not succeed, unless the bar, during its progress, be held in its position by the roller; otherwise it will twist round and adapt itself to the same situation in the rolls that it before occupied, the streak, or *finn*, as it is called, still remaining."

Small iron is not manufactured in the same way as the large; instead of piles, *billets*, or single pieces of bars, are used, cut into lengths adapted to the size of the finished bar. Small iron requires to be rolled at a greater speed than large sizes, as it becomes cold so much sooner. Very small sizes are rolled in long lengths, often as much as forty feet, and are afterwards cut into two or three lengths for the market. The bars thus rolled have a better appearance than short lengths, and are no more trouble to the roller, who can roll a long piece with as much facility as a short one. It is of importance that small iron should be smooth in appearance and accurate in size; and to ensure these desirable qualities, the small rolls are *casehardened* in the casting. This is done by running them into a thick solid iron mould, the effect of which is to cool the iron suddenly on the outside, thereby giving it the hardness and appearance of white iron on the surface, the inside remaining dark grey or bright.

When the rolling is complete, the bars are straightened, which is done by boys on a long bench of cast iron; they are then stamped with some letter or mark to distinguish the works where they are made; the ends are next cut off with powerful shears, and they are then ready for the market. Small iron is put up in bundles, each containing a hundred-weight or only half that quantity.

In most of the large iron works iron is sent out in other forms than those of bars. The vast extension of our railroad system, the use of iron ships and steam boats, and other causes, have increased the consumption of iron to an enormous extent, so that the manufacture of boiler plates, iron rails, tires for wheels, &c. now forms an important addition to the labours of the forge. There is also a constant demand for sheet iron of all sorts, hoop iron, spade iron, split nail rods, &c. as will be further noticed in the next treatise.

Boiler plates and sheet iron are rolled between perfectly plain rolls, as shown in the frontispiece. This is laborious work for the rollers, especially as the plates often weigh many hundred-weight each,* and the very large extent of heated surface causes the men to be constantly bathed in perspiration. "The iron for them is prepared by making a pile of rough bars, which is heated in a puddling or balling furnace, and brought under the forge hammer, where, by repeated blows, it is beaten into a solid slab of about two or three inches thick and nearly square, long and broad according to the weight and shape of the boiler plate for which it is destined. It then requires to be again heated, as it has become too cold under the hammer to be rolled at the same heat: when heated again it is rolled to the proper thickness, the rolls being brought nearer to each other by screws every time it passes between them. It is also brought to the required shape by passing it through the rolls in different directions, sometimes lengthwise, and sometimes with the side or one corner foremost. A skilful roller will in this way bring it very nearly to whatever dimensions are wanted, so that the ragged and uneven edges which are afterwards to be cut off shall amount to as trifling a sum as possible."

---

* Some of the plates used in the construction of the *Great Eastern* steam-ship are 28 feet in length, and 1¼ inch in thickness, weighing 2¼ tons each. These are among the largest plates ever rolled.

VARIETIES OF MANUFACTURED IRON.

There are various qualities of bar iron as of every other manufactured article. There are three qualities known in the market by the names *common iron*, *best iron*, and *best best* or *chain cable iron;* the materials for the superior sorts being selected with greater care, and special attention being paid to the puddling. In making the best iron, *scrap iron*, or the short imperfect pieces cut off the ends of the finished bars, is used in the balling furnace. The manufacture of cable bolts will be noticed in the next treatise.

Two common defects of bar iron have given rise to the well-known names of *red short* and *cold short.* Red short iron is that which cracks when bent or punched at a red heat, although it may be very strong when cold. Cold short iron, on the contrary, is weak and brittle when cold, but can be worked without difficulty when hot. " The method of trying the quality of iron is to nick a bar at one side with a chisel, and then to break it, or double it down, as the case may be, at the notch. If the iron is cold short, it will break off at once with a blow of the sledge hammer." The cause of iron being red short appears to be overheating in the balling furnace. "If upon trial the bar should be of good quality, instead of breaking short off it will bend double, and those portions of it to the depth of the notch on both sides will separate a little from the body of the bar, and split up, just as a piece of fresh ash stick would do, and will exhibit a clear, distinct, silky fibre. If this appearance is shown on the trial of the bar cold, and if it is then taken to the smith's shop and bent double at a cherry-red heat, first in the direction of the pile and then at right angles to it, without being at all cracked on the outer side of the bend, it may safely be pronounced to be of excellent quality, neither red short nor cold short." A cold short iron is generally produced from a lean ore, in which case it has been found desirable to mix with it the rich red hepatic ore of Lancashire and Cumberland, which if smelted by itself would produce a very red short iron. In this way two opposite defects are made to correct each other, and iron of average strength is produced. This richer ore does not require roasting, but is put into the furnace in the state in which it is brought from the mine.

Another variety of manufactured iron is *charcoal iron*, so called on account of charcoal being used in the refining. When the bloom is removed from the charcoal fire, it is placed under a heavy hammer and beaten out flat, in which state it is called *stamped iron*. It is then broken up into small pieces, piled, heated, and again hammered out into a regularly shaped slab of about a hundred pounds weight. This sort of iron is peculiarly tough and strong, and is much used for drawing into the best descriptions of wire, such as those used for carding;* it is also in great request for rolling into thin sheets for the use of the tin-plate manufacturers.

---

* See the treatise on the Manufacture of Cotton Yarn, Part II.

STATISTICS OF THE IRON MANUFACTURE.

In the first edition of this treatise, published in the year 1848, it was stated that the means for ascertaining the quantity of iron produced in Great Britain were not very precise. Since that time, however, Government has connected with the Geological Survey of Great Britain and the Museum of Practical Geology, a department for Mining Records under the able superintendence of Mr. Robert Hunt. From a volume, entitled "Mineral Statistics of the United Kingdom for the year 1856," we learn that during that year no less than "10,483,309 tons of iron ore have been raised, and 3,636,377 tons of pig iron have been produced. Iron ores have sold, according to their respective qualities, at the mines, for prices varying from 5*s*. to 15*s*. per ton. The mean average price of iron ore, computed from the sales of all the districts, has been 11*s*. per ton. This will give 5,695,815*l*. as the value of the iron ore produced in 1856 in Great Britain. The total produce of pig iron, at the mean average market price, or 4*l*. per ton, will give a money value equal to 14,545,508*l*."

The following table will show the distribution of the iron trade in Great Britain in 1856 :—

	Tons.
Northumberland and Durham	331,370
Yorkshire	275,600
Derbyshire	106,960
Lancashire and Cumberland	25,530
Shropshire	109,722
North Staffordshire	130,560
South Staffordshire and Worcestershire	777,171
Gloucestershire	24,132
North Wales	47,682
South Wales (Anthracite districts)	62,400
Ditto (Bituminous districts)	814,750
Scotland	880,500
Total produce of Great Britain	3,586,377

In the years 1855 and 1856, the quantity of British iron exported was as follows :—

	Tons.	Tons.
Pig Iron	291,776	357,326
Bar iron	519,846	673,077
Bolt and rod iron	21,146	28,796
Cast iron	70,138	72,394
Iron wire	5,923	9,190
Anchors, grapnels, &c.	24,042	28,146
Hoops	33,294	38,659
Nails	7,603	11,281
All other sorts of wrought iron except Ordnance	82,175	172,204
Old iron for re-manufacture	20,099	25,969
Unwrought steel	16,693	21,858

Of British hardware there were 34,728 tons 12 cwt. of the declared value of 3,747,598*l.* exported in the year 1856.

In the year 1858 the quantity of iron ore raised in the United Kingdom was 8,040,959 tons, producing 3,456,064 tons of pig iron, the value of which at the furnace being taken at 3*l.* per ton, makes the total value of the produce 10,368,192*l.*

The above quantity was produced by 332 blast furnaces in England, 153 in Wales, and 132 in Scotland.

Digitized by Google

Digitized by Google

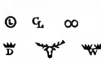
Digitized by Google

THE MANUFACTURE OF STEEL.

Iron, in its manufactured state, is always mixed with carbon and other substances; its pure form being known only to the scientific chemist. The carbon of manufactured iron seems to be in a state of mechanical mixture with the metal; but when by a peculiar process a minute portion of carbon (varying from 0·7 to 1·7 per cent.) is chemically combined with it, a *carburet of iron*, or steel, is produced which possesses some remarkable qualities, whereby it is distinguished from iron and fitted for uses to which that metal is inadequate. Steel is so much harder than iron, that it is capable of cutting and filing it; steel scratches the hardest glass, strikes sparks with siliceous stones, is denser, has a finer grain, assumes a brighter and whiter lustre when polished, acquires greater elasticity, retains magnetism longer, and does not rust so easily. When heated it assumes various beautiful tints of colour; and if suddenly cooled it becomes harder, more brittle, and less pliable than iron. Indeed, the chief value of steel depends on this useful property, for it may be made extremely hard or be tempered to any degree between extreme hardness and softness.

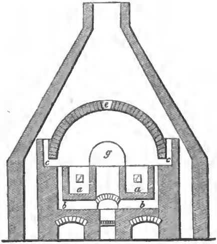
The iron manufactured in this country is not sufficiently pure for conversion into steel, the charcoal iron of Sweden and Russia being chiefly used for the purpose. The charcoal iron made at Ulverstone, and a similar iron from Madras, may also be used. The foreign iron is imported in bars, on which certain marks are stamped by the manufacturers, whereby the iron is recognised in the market. The most celebrated iron mine of Sweden is that of Dannemora, situated about thirty miles to the north of Upsala. Although this mine has been worked for four centuries, it still yields the best iron in Europe. The ore contains limestone, quartz and actinolite, and affords from 25 to 75 per cent. of cast iron. The ore is first broken into small pieces and roasted; it is then put into conical-shaped furnaces, constructed of the slag from cast iron. Here it is mixed with charcoal, and then melted and separated from the slag. The cast iron obtained in this manner is as white as silver, completely crystallized and very brittle. The cast iron is converted into malleable iron by heating it in a bed of charcoal and hammering it out into bars. In this state it is whiter than common iron, and is less liable to rust; it is distinctly fibrous in texture, and much stouter than any other iron.

This mine yields annually about 4000 tons of iron, the whole of which is sent to England to the port of Hull; where it is known by the name of *Oregrund iron,* from the port at which it is shipped. The marks which distinguish this iron are the hoop L (so called from the letter L being inclosed in a hoop); GL and double bullet. These are shown in the annexed engraving. The iron bearing the first mark sells at 40*l.* a ton; that bearing the second at 39*l.*; the best Russian mark, the CC. N.D., seldom fetches a higher price than 20*l.* per ton.



The cause of the superior quality of the Dannemora iron has not been explained. Some chemists suppose it is due to the presence of manganese; Berzelius attributed it to the presence of silicon; and others suppose it to arise from the nature of the process employed. Inferior Swedish iron is also imported at a much lower cost, such as that bearing the marks C and crown, D and crown; Steinbuck; and W and crowns. These marks are given in the preceding wood engraving.

Iron is converted into steel in what is called a *cementing furnace*, which is a conical building re-

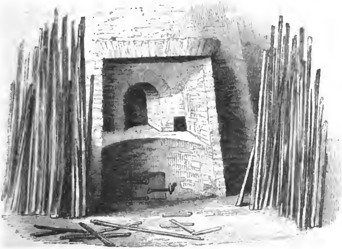


SECTION OF CEMENTING FURNACE.

sembling a glass house externally, the upper part being terminated in a dome or cone. Within the furnace are two chests or troughs, *a a*, in which the bars of iron are buried in pounded charcoal. These troughs are made of fire tiles or fire-stone grit, and are capable of holding about twelve tons of bar iron. They are from 8 to 15 feet long, and from 26 to 36 inches in width and depth; but those of small capacity are said to produce steel of most uniform quality. Below and between the troughs, and extending their whole length, is a grate open at each end, where it is supplied with fuel, and the fire is kept up as equably

Digitized by Google

as possible during the process, the flame being directed equally round the troughs by a number of air holes, *b b*, and flues, *c c*, leading to the chimney. The draught is further aided by an opening, *e*, in the middle of the arch of the furnace. The troughs are, of course, filled before the fire is lighted (the workman entering the furnace by the opening at *g*), and the preparation of charcoal dust, called *cement*, varies with different steel converters: charcoal, made from hard wood, is preferred; but soot is sometimes used; as also a proportion (about one-tenth) of wood ashes and of common salt. The workman sifts this mixture to the depth of two inches over the bottom of the troughs; puts in the bars upon their narrow edges, with a space between every two bars of from a half to three-quarters of an inch; powder to the depth of an inch is then sifted over this layer; a new series of bars is next made to fit into the interstices between the first, care being taken that no two bars are in contact, and in this way the troughs are filled to within six inches of the top. The filling is then continued with old cement powder, and this is lastly covered with refractory damp sand or fire tiles for the purpose of excluding the air, which, if admitted, would greatly injure or altogether stop the process of cementation. The entrances to the furnace being carefully closed, the fire is lighted below the troughs and carefully urged for two, three, or four days, until the proper cementing heat is attained: this heat is maintained during several days more until the iron has absorbed the quantity of carbon requisite to form the kind of steel required by the manufacturer. From six to eight days are sufficient for the production of moderately hard steel, such, for example, as that known by the name of *shear* steel; softer steel for saws and springs requires a shorter time; harder steel for making the chisels used in cutting iron takes a longer period; and for some purposes bars are exposed to two or three successive processes of cementation, and are hence said to be *twice* or *thrice converted.*



MOUTH OF CEMENTING FURNACE.

At one end of each trough is a hole, called the *tasting hole, f f,* by which the workman can occasionally draw out a bar to see how the transmutation is going on. This is judged of by the *blisters* which appear on the surface of the bars, which gives the well-known name of *blistered steel* to this article. When by this process of *tasting* the change is judged to be complete, the fire is extinguished and the furnace left to cool for about a week, when the process for making blistered steel is finished.

This steel is very different from the bar iron from which it was produced. Its surface is covered with blisters, and on breaking a bar across, its texture is seen to be no longer fibrous, but granular or crystalline; the colour is white like frosted silver, and the crystals are large in proportion to the amount of carbon absorbed.

Steel may also be produced by heating the bars in carburetted hydrogen gas. The process is more rapid and the results are more uniform than the method by cementation. *Natural* steel, as it is called, is prepared by heating the best cast iron on the refining hearth, as in the operation which precedes puddling. See Manufacture of Iron, page 56. The oxygen burns off a portion of the carbon from the cast iron and steel remains. The mass is rendered uniform by forging; but the product is of inferior quality, fit for agricultural implements and springs for machinery. Mr. Bessemer's method of making steel resembles his process for refining iron (already noticed, Manufacture of Iron, page 62), only he stops short in the operation after burning off a certain quantity of carbon by the injection of atmospheric air into the apparatus containing the molten cast metal.

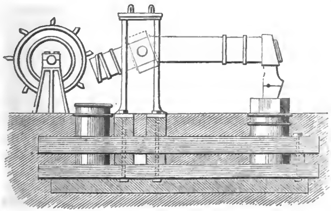
TILTING.

The bar of blistered steel contains numerous fissures and cavities, which render it unfit for forging except into a few rough articles. To prepare it for forging into edge tools and cutting instruments, it requires to be condensed and rendered uniform, which is the object of the next process, called *shearing*, the *shear steel* thus produced being originally employed in the manufacture of shears for cutting off the wool from sheep.* The process is also called *tilting*, from the circumstance of a tilt hammer being employed.

In some respects the operation of tilting resembles that of *shingling* described in the *manufacture of iron;* but the tilt-hammer is differently arranged. In shingling, where only a slow motion is required, the hammer is lifted up by means of levers attached to a cam revolving under the nose of the helve. In the tilt hammer the cogs of a wheel are made to act on the tail of the helve, pressing it down, and thus causing an elevation of the head of the hammer, and a rapidity of motion, which could not evidently be

---

* Shear steel is also sometimes called *Newcastle steel,* from the circumstance of steel of this quality having formerly been made at Newcastle; a better quality introduced from Germany gave rise to the term, *German steel.*



TILT HAMMER.

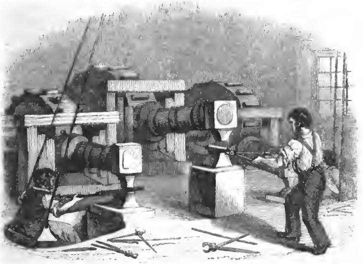
produced by the arrangement of the shingling hammer; for, in this, the levers must be sufficiently wide apart, to allow the hammer head a clear space to fall through. In the tilt hammer, however, where the motion is applied at the tail, the number of levers may be considerably multiplied; because, from the position of the axle, the tail describes a very small arc between every two levers; and this small motion will cause the head to pass through a much larger space in the same time, thereby producing rapidity of motion, and considerable force. The construction of the tilt hammer will be better understood from the preceding figure. The framework is strongly secured to the masonry of the foundations, so as to form a firm bed for the block. The shaft of the hammer is made of timber secured by wrought iron rings and fitted into a cast-iron socket with trunnions or axles cast upon it, which turn in brasses in a

Digitized by Google

block. The wheel by which the hammer is elevated is furnished with ears or *tappits*, which, during the revolution of the wheel, engage the end of the shaft and continue to depress it until disengaged, when the hammer head falls with considerable force on the anvil, producing in this way from one hundred and fifty to three hundred and sixty strokes per minute.

The blistered steel is prepared for tilting by breaking the bars into lengths of about eighteen inches, and binding four or more of these into a faggot by means of a slender steel rod. One of these fragments is left longer than the rest to serve as a handle, or a pole of iron is used for that purpose, as shown in the following figure. The faggot is then raised to a welding heat in a wind furnace, and is covered with sand to prevent it from wasting or burning away. When first removed from the furnace it is placed under a forge hammer, which unites all the fragments and closes up internal fissures. The rod thus produced is again heated, the binding rings are knocked off, and the tilt hammer comes into operation. The workman is seated on a board, suspended by iron rods from the ceiling of the mill-house; whereby he is enabled, with a very slight motion of his foot, to advance or recede with ease and rapidity, so as to cause every part of the bar to receive the blows of the hammer in quick succession. As the anvil is nearly on a level with the floor, the workman is seated in a kind of pit excavated for the purpose; he is attended by two boys to bring hot rods and to remove them after they are hammered. "In small rods, the bright ignition originally given at the forge soon declines to darkness; but the rapid impulsions of the tilt revive the redness again in all the points near the hammer;

so that the rod skilfully handled by the workman progressively ignites where it advances to the strokes. Personal inspection alone can communicate an adequate idea of the precision and celerity with which a rude steel rod is stretched and fashioned into an even, smooth, and sharp-edged prism, under the operation of the tilt hammer. The heat may be clearly referred to the prodigious friction among the particles of so cohesive a metal, when they are made to glide so rapidly over each other in every direction during the elongation and squaring of the rod."



TILTING STEEL.

A visit to the tilt house is by no means pleasant to a stranger; several hammer heads, each weighing from 150 to 200 pounds, falling from three to four hundred times per minute upon solid metal anvils, produce a stunning noise, and a vibration which can be felt through the whole body. This vibration is checked as much as possible by carrying the foundation of the tilting apparatus to a depth of ten or twelve feet, forming a heavy mass of masonry; and the anvil is made to rest on a massive wooden pillar strongly secured by wrought iron rings, which is supported by, and forms part of, the masonry.

By tilting, the steel is formed into bars of about an inch and a half broad, and three-eighths of an inch thick; all the loose parts and seams of the blistered steel are closed, and it is now capable of being polished, which was not before the case: it is also more malleable, and can be forged with the hammer into shears, edge tools, and cutting instruments, as will be noticed further on. The value of the steel increases with the amount of tilting which it receives: it is therefore not uncommon to cut a tilted bar into several pieces, form them into a faggot, and elongate this again into a bar or rod. The terms *double shear*, *single shear*, and *half shear*, express the amount of doubling and welding which the bars have received.

CAST STEEL.

Steel is produced in the greatest perfection by the process of *casting;* that is, the bars of blistered steel, being broken into fragments, are melted in crucibles and then poured, while in a fluid state, into ingot moulds. The heat required to produce this fusion is greater than that required for any other process in the manufacturing arts; the crucibles or melting pots are therefore made with the most refractory fire clay and with the greatest care, in order to exclude bubbles of air and extraneous substances, which might expand or ignite in the furnace, and thus endanger the stability of the melting pot.

The crucibles are made of Stourbridge or Derby clay, kneaded into a perfectly uniform and smooth mass. It is first mixed with water and worked up, and then spread out in a thin layer on a shallow trough on the floor. There it is kneaded during five or six hours by the naked feet of two men, who with a shuffling kind of motion go over every part of the surface, pressing it down quite flat; and so sensitive is the touch of their feet (which are developed to an enormous size by this constant exertion), that they can, by the difference in the tread, detect an air bubble, a fragment of straw or of dirt in the clay. The two latter they pick out with the fingers, and get rid of the air by making a slight incision with a knife. When the whole surface has been well trodden over it is folded double and trodden out again, so as to occupy the whole of the trough. If the reader has ever watched the domestic operation of making pastry, he will be able to form a good idea of the process of kneading clay for the steel melting pots.

PREPARING CRUCIBLES FOR CAST STEEL.

The crucibles, which are about two feet in height, and somewhat of the shape of a barrel (1), are formed between a mould, consisting of a solid block of wood (2), and an outer core (3), each furnished with two handles. This being rammed full of the kneaded clay, the inner mould is

1

forced vertically into it until it reaches the bottom. Each crucible, which weighs about 25lbs. is removed as soon as it is finished into a heated vault, where it gradually becomes dry; and some hours before being used the crucibles are brought to a red heat for the purpose of annealing them. A crucible can seldom be used for melting the steel more than three times without cracking; so that there is a constant demand for crucibles, as many as from one to two hundred being made in one steel refinery in the course of a week.

3

On a level with the crucible-making department are the furnaces for making the steel; these are ten small glowing cavities, arranged side by side, in a kind of vault, the draught passing out by the back of each into a tall chimney connecting the whole. Each furnace is only just large enough to contain two crucibles and the proper amount of fuel; and it is lined with a plaster calculated to resist the intense heat. This plaster is formed of the dust of the roads in the vicinity of Sheffield, and obtains the odd name of *ganister*. The fuel employed is a dense well-made coke, broken into lumps of about the size of a hen's egg. No blast is employed to urge the heat, a skilful arrangement of the draught being sufficient for the purpose. Immediately over each furnace is a trap-door, made of fire bricks fastened in an iron frame, opening into the casting house, which is a kind of shed entirely open on one side, while on the other ten trap-doors are seen, from the sides of which escape a few rays of red light, indicative of the fiery furnaces below. In an adjoining shed the bars of blistered steel are broken into fragments, and the charge for each crucible weighed out into tin trays, a small portion of black oxide of manganese being added to each charge, this substance being supposed to improve the quality of the steel. In some cases powdered charcoal forms part of the charge.

The empty crucibles are put into the furnace upon a sole of baked fire clay, and the charge is given to each by means of a long funnel of iron plate. Each pot is carefully covered over with a lid of a more fusible clay than the body of the crucible, and sometimes a small quantity of bottle glass or blast furnace slag is put in above the steel fragments, so as to form a sort of vitreous coating to prevent the air from oxidizing the metal. When the pots are thus charged and covered in, the furnace is filled up with coke and kept well supplied. In about four hours the steel is in a state for casting, and as the time approaches the men occasionally lift up the various trap-doors and examine the crucibles, their eyes being accustomed, through the fierce floods of heat which pour upwards from the furnace, to detect the precise time when the metal is sufficiently fluid for casting.

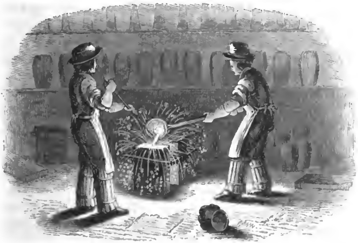
While the steel is melting, the ingot moulds are prepared. These moulds, which are of cast iron, are of various sizes, according to circumstances; those which were used at the time of the writer's visit producing an ingot about two inches square, and two feet in length, a quantity equal to the contents of one crucible. When an ingot of unusually large size is required, such as for rolling into a piston-rod or a large plate for a circular saw, the mould is, of course, of proportionable size, and receives the contents of two or more crucibles. Each mould consists of two parts, forming a long hollow cavity, the parts fitting accurately together, and held together by a clamp of iron: they are kept upright by resting against the angles of a pit in the floor of the casting-house. Previous to putting the moulds together, the interior is smoked by being laid across a pitch fire, the internal coating of carbon thus imparted preventing the liquid steel from adhering to or melting the mould.

Just before drawing the crucibles, each man puts on sacking leggings, and an apron of the same material: he next visits a tank, and thoroughly soaks these in water, as a further protection against the fierce heat to which he is about to be exposed; then, throwing open the trap-door of one of the furnaces, he removes a portion of the white-hot coke, and, planting his feet one on each side of the yawning fiery furnace, thrusts down a pair of tongs furnished with concave jaws for grasping the crucible just below the swell, and then, with a motion between a jerk and a swing, raises the glowing burden. A second man immediately removes the cover; a third man, and the most skilful, grasps the crucible with tongs held horizontally, raises it, and slowly inclines it to the mouth of the ingot mould, his attendant, with a pair of tongs, removing any portions of cinder or slag from the surface of the molten metal. Considerable skill is required in *teaming*, as the operation

DRAWING THE CRUCIBLES.

Digitized by Google

of transferring the metal from the crucible to the ingot mould is called. It must be poured directly down the centre of the mould, without touching the sides: for were it to do so, it would instantly remove the carbonaceous covering, and burn a piece out of the mould. The metal flows as liquid as water, and with the gurgling sound of water when poured under similar circumstances; but the extremely high temperature of the molten steel is shown by the white heat slightly tinged with blue. As the stream falls, minute portions of it combine rapidly with the oxygen of the air, and take fire, producing brilliant scintillations. The fire even communicates itself to the ingot towards the end of the process of teaming, and the mould then appears like a brilliant firework; but this combustion is soon stopped by the insertion of a solid plug. As the ingot immediately solidifies, each mould is opened directly after the teaming, and the ingot is turned out in a red-hot state. This rapid cooling of the steel and the thin film of soot



TEAMING.

effectually protect the mould from the destructive action of the liquid metal, which would otherwise ensue. The men engaged in these operations have that peculiar look about the eyes which shows the nature of their occupation; but otherwise, we believe, the business of steel refining is not considered unhealthy, and the men receive good wages.

As soon as the crucible is emptied of its contents, it is returned to the furnace, to receive a fresh charge; and as four hours are required for the melting, there are three casts in the twelve hours, during which the men work.*

---

* In preparing this notice of the Manufacture of Steel, the writer has to acknowledge the personal kindness, to himself and the artist, of Mr. Burgin, steel converter, Messrs Spenser and Son, and Messrs. Naylor, Vickers, and Co., steel refiners, all of Sheffield.

MANUFACTURES IN IRON AND STEEL.

THE FOUNDERY.

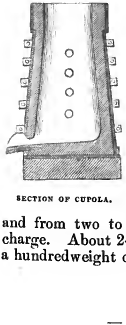
The forge and the foundery are the two most important places connected with the formation of all the large pieces of machinery, the utensils, the pillars, and other forms in which iron is produced on the large scale. In the forge, as was described in a former treatise, the pig iron is made malleable, and is wrought into bars of various shapes, which can be further hammered, and modified, and adjusted to the particular purpose required by the engineer. In the foundery the pig iron is melted, and reproduced in an endless variety of forms, by casting in moulds. The iron, however, does not acquire malleability in the process—it still retains its brittleness, and does not admit of being greatly altered by the tool, except for the purposes of burnishing, planing, or otherwise polishing or finishing.

The casting of "a sow of pigs," already described, will convey a rough idea of the business of the foundery; but the production of cast-iron articles, which are intended for ornament as well as use, calls for a number of additional details, and much skill on the part of the founder. He has also to mix several qualities of iron, so as to produce certain desired properties in the castings: one piece may require great strength and tenacity, to bear heavy weights and strains; another must yield readily to the chisel or the file; a third may require to be very hard; a fourth must resist sudden changes of temperature; and so on.

Google

The foundery is usually a spacious room, the floor of which, to the depth of a yard or thereabouts, is covered with loamy sand and charcoal powder, already used in former castings. There are also several pits from five to seven yards deep, for the purpose of burying the moulds for large castings, so that the metal may be conveyed to them from the furnace by channels formed in the sand. These pits are lined with brickwork, and, when not in use, are usually left full of moulding sand. The floor of the foundery requires to be kept perfectly dry, any dampness in the large moulds being likely to produce fatal explosions by the sudden expansion of the steam which would form the moment the molten metal came in contact with moisture.

The foundery is furnished with air or reverberatory furnaces, which are used for melting large quantities of metal, and also with small blast furnaces, called *cupolas*, which are used for smaller quantities. A cupola consists simply of a cast-iron cylinder, lined with sand or fire bricks, furnished with side openings at various elevations for admitting the blast at the point where it is wanted. Each hole can be closed by a small cast-iron plate sliding in grooves. At the side, near the bottom, is an opening for letting the metal flow out, for which purpose a cast-iron gutter lined with loam is inserted. The furnace is first filled with ignited coke, and when this begins to sink, alternate charges of coke and pig iron are thrown in every ten or fifteen minutes. The pigs are broken into lumps of 14 or 15 lbs. weight, and from two to five hundred weight constitute a charge. About 24 lbs. of coke are required to melt a hundredweight of iron.



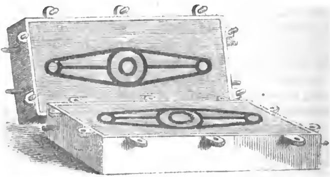
SECTION OF CUPOLA.

In executing an article in cast iron, it is necessary to have a pattern, in order to give to the sand the impression of the form which the metal is to assume. For various ornamental castings, statues, &c., the *model* is made in clay, and requires the educated hand and eye of an artist; but for the different parts of machines, and for common utensils, the *pattern* is generally made of wood by a carpenter. The modelling and pattern departments are very important adjuncts to a well-appointed foundery: the pattern-maker must be a good carpenter, and also well acquainted with the founder's art, so as to be able to arrange the different parts of the pattern with reference to the greatest convenience in casting. If the pattern is not very large, it is usually made of mahogany; in large patterns deal is used, and especial care taken to prevent warping. The pattern is also made larger than the article in metal is intended to be, on account of the contraction of the latter in cooling. An allowance of about one-eighth of an inch per foot is made for this purpose.

There are three varieties of casting: 1, in moist or green sand; 2, in dry sand; and 3, in loam. The first and second methods are similar, the one being used for the finest work, and the other for larger articles intended to be painted, or where a rough surface is of no importance. Loam casting is generally used for cylindrical or circular articles, as will be further explained hereafter.

Green sand is a mixture of new fresh sand with about one-twelfth of charcoal, made sufficiently adhesive by moisture to preserve the forms impressed on it. This mixture cannot be used more than once in fine castings; therefore, for the sake of economy, it is made to form only that portion of the mould which is next the pattern, to the thickness of about an inch; this is called the *facing sand*, the rest of the surrounding space being filled with the sand of the floor used in former castings, which, being of a coarser and *freer* consistency, facilitates the escape of air and moisture.

The mould is formed within a couple of iron frames called *flasks ;* they are furnished with handles for the convenience of lifting, and also with ears, which correspond exactly with each other in the two flasks: one set of ears is perforated, and the other has projecting pegs, so that the two flasks can be accurately adjusted after having been separated.



FLASK CASTING.

The lower flask is first prepared by placing it on a board and filling it with sand well rammed down. The pattern is then pressed down into the sand until it is half immersed; the workman then smoothes the sand up to the sides of the pattern with a small trowel. The other flask is now put on, and fine burnt sand, or wood charcoal in fine powder, tied up in a linen bag, is dusted over the lower surface, to prevent it from adhering to the sand, which is now to be put into the upper flask. Channels are also moulded on the lower surface, for the introduction of the melted metal: these are formed by half burying some rods of wood extending from the pattern to the side of the frame. The upper flask is now filled with sand, and well rammed down with the tool represented here. The rods of wood

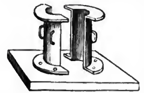
Google

are removed, whereby openings are left from the side down to the pattern. A small iron rod is next inserted in all directions from the pattern, for the purpose of allowing the escape of air and the expansion of steam from moisture when the hot metal is poured in. The upper flask is now lifted off, and the pattern carefully taken out, by inserting at each end the point of the screw shown in the following figure. Any little defects in the mould are next repaired by means of damp sand, which is applied and gently pressed with a trowel and various other tools; weak parts are also supported by means of wire pins. The mould is then dusted over with fine charcoal, and gently polished with a small trowel. The upper flask is next carefully placed in its proper position; the two are locked together with cross pins or wedges, and the mould is fit for casting. The molten metal is brought from the cupola in an iron ladle or pot, lined with a coat of loam, and poured in an equal stream into the channels left in the flask for the purpose.

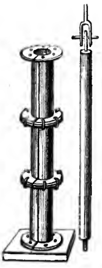
Casting in dry sand is similar in principle to the foregoing, subject, however, to such variations as the size and shape of the article require. By this method the various pots and pans, ranges and ovens, in domestic use, are produced; also frames for machinery, spandrils for roofs, doors, window-frames, and similar articles, which do not include a central hollow core. Bridges are also commonly formed of iron; and the writer could not but regard with great interest, on his visit to Colebrook Dale, the first iron bridge ever erected. It crosses the Severn at a village appropriately called Ironbridge, and is situated within about a mile of the Company's foundery. There is some dispute as to the originator of iron bridges: it is, however, generally agreed that an architect named Pritchard, in the year 1773, sug-

IRON BRIDGE CROSSING THE SEVERN IN COLEBROOK DALE.

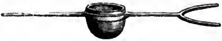
gested the practicability of constructing wide iron arches, capable of spanning such a river as the Severn, and that this bridge was constructed chiefly after Mr. Pritchard's plans.



Hollow tubes, such as gas and water pipes, are also cast in sand, for which purpose half-cylinders are used instead of the flasks before described. At the commencement of the process two half-cylinders are set up securely, and a smooth plug or mandril let down into it, and made to rest on a hole at the bottom, being also kept firm at the top by a contrivance shown in the figure on the next page. This mandril being of smaller diameter than the cylinders, there is evidently a vacant space between the two; this is filled up with moist sand, well rammed down. A second pair of half-cylinders is then added to the first, and sand is rammed in as before; a third pair is added to the second, and more sand added: this com-



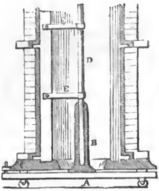
pletes a length of nine feet, which is the usual length of a cast-iron water-pipe. The mandril is now carefully withdrawn by means of a windlass, and the cylinders, with their lining of sand, removed to the drying-stove. The next part of the process is to form the *core*. This is done by the following contrivance. A four-sided bar, about a foot longer than the intended pipe, with a band of hay or straw wound round it, is inserted in a tube of the exact size of the intended core, and then filled up with mortar made with sand loam, horse-dung, and hair. This being sufficiently solid, the core is drawn out of the tube, and thoroughly dried before a fire. The cylinders, with their lining of sand, are now set up in a pit, and the core carefully adjusted, filling up the said tube, with the exception of a space between the outer surface of the core and the inner surface of the sand tube, which evidently gives the thickness of the intended pipe. The core is kept in its place at the bottom by a projecting piece of the iron bar, which fits into a centre socket, and at the upper part it is adjusted to the centre by a collar of clay. A quantity of molten metal is then poured in by an opening at the top. It is conveyed from the furnace in an iron pot lined with loam, by a contrivance shown in the figure; or it is allowed to flow along a channel in the sand, from the furnace to the mould. In rough work the metal is sometimes cast at once into pipes instead of pigs, as it is drawn off from the blast furnace.



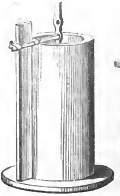
When the metal is sufficiently cool, the mould is hoisted out of the pit, the outer cylinders are removed, the core is taken out, and the pipe is ready for use, provided no flaws are detected in the casting.

For casting very large cylinders, such as the cylinder of a steam-engine, the principle is the same as that employed for casting pipes, as it is evident that a steam cylinder, of whatever size, is nothing more than a large pipe; but the great size of the article calls for certain practical variations, which will be understood by referring to the following figures. No. 1 is the section of a mould for the cylinder of a steam-engine. It is placed upon an iron frame A, mounted upon wheels, for the convenience of moving the mould to different parts of the foundery, as may be required. In the centre of this frame is fixed a tube or cylinder B: *c* is a ring of iron, with four ears or flanches, for the purpose of lifting it. This ring is placed on the frame A, as nearly as possible concentric with the tube B. Upon this ring a thickness of sand is first placed, and upon the sand a cylinder of brickwork is constructed, clay or wet loam being used instead of mortar. The inner diameter of this cylinder exceeds by a few inches the

1.



2.



3.

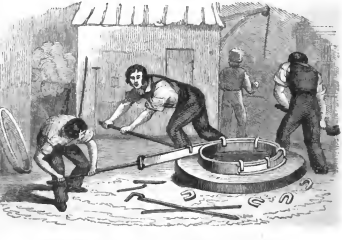
outer diameter of the intended steam cylinder. The inner surface of the brick cylinder is next covered with loam, which is smoothed round, and made to assume the exact shape of the outer surface of the steam cylinder by the following contrivance. A rod D, furnished with arms E, is dropped into the tube B, and to these arms is bolted a piece of wood properly shaped, which, by its revolution upon its centre D, moulds the wet loam to the shape of the steam cylinder. This completes the outer mould, which is removed to an oven to be thoroughly dried, or a fire is kindled within it for the same purpose. The central core of brickwork is formed in a similar manner; but in this case the outer surface is covered with wet loam, and is brought to the shape and dimensions of the inner surface of the steam cylinder by placing the mould board on the outside, as shown in fig. 2. This core is also made dry by baking. A pit is then prepared in the foundery of sufficient depth to contain the mould, into which it is lowered by the apparatus shown in fig. 3, attached to a crane, the chains from the four arms descending to the ears in the bottom plate *c* of the mould. When the mould and core are let down into the pit and properly adjusted, the hollow core is half filled with sand well rammed down, for the purpose of giving it steadiness; a flat cover of dried loam is then put over both mould and core, a number of holes being left in this cover for pouring in the metal. Small ditches or channels are made from the furnace to the pit, and everything is now ready for casting. It will readily be seen in this, as in former instances, that the molten metal flowing into and occupying the space between the inside of the mould and the outside of the core forms the steam cylinder. Any letters, figures, or other device in relief required on the metal, must, of course, be previously sunk into the loam forming the inner lining of the mould.

The processes both of the forge and of the foundery

Google

are subject to continual change, as new machines or new methods of making old ones are introduced. It would at first view be supposed that little novelty could be introduced into the methods of making an iron wheel; a visit, however, to an extensive railway engineering establishment enabled the writer to witness a number of highly ingenious and novel details in the manufacture of railway-carriage wheels.

A straight bar of angle iron* of the requisite dimensions is raised to a red heat, and then brought to a circular mandril, round which it is gradually bent by the following contrivance:—one extremity is first secured by a staple to the mandril, then with the assistance of a sledge hammer, and the bars marked 5 in the cut at page 28, the parts nearest the attached extremity are brought up to the mandril and well secured by staples; this process is repeated until the whole bar is bent round and the two extremities

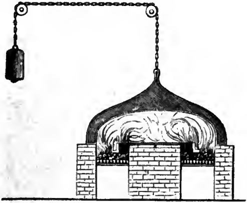


BENDING THE TIRE FOR RAILWAY-CARRIAGE WHEEL.

---

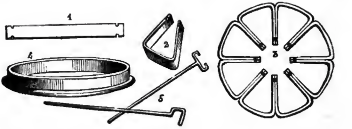
[*] Iron rolled into such a shape that its cross section forms an angle, thus, ⌊. There are many forms of angle iron.

meet or nearly so, their complete union being effected by a couple of wedges of iron driven between them at a welding heat. The tire thus formed (No. 4) is next placed in a furnace, and brought to the proper heat preparatory to putting in the spokes. The construction of this furnace is peculiar. It was considered that in order to heat a ring of metal, such as the tire, a ring of fire only was required, and therefore a *ring-furnace* was constructed; that is, a central core of solid brickwork was formed, round which was built a fireplace and hearth. If all this were closed in by a chimney, it would require a very large door or opening to put in and take out the tire; it was therefore determined to cover it in with a moveable dome balanced by a weight passing over a pulley, so that in order to put the tire into the furnace all that was necessary was to throw up this dome, slip in the ring, and lower the dome upon it.

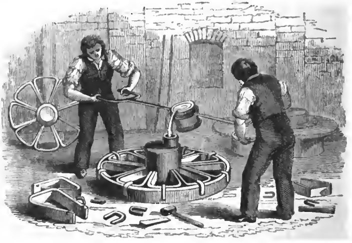


RING FURNACE.

Leaving the tire in this ingenious ring furnace, the formation of the spokes must next be noticed. The spokes are arranged in the form of arches, each arch being produced from a bar of wrought iron (No. 1) bent round a mandril into the shape shown in No 2, eight of these bent bars or arches being arranged as



in No. 3, to form a complete set of spokes. These are all united by the nave, which is cast solid; for this purpose the spokes are fixed within a mandril, their centres terminating in flasks, in which the proper shape of the nave has been moulded. Molten iron is poured in, as shown in the following engraving,



CASTING THE NAVE OF A RAILWAY-CARRIAGE WHEEL.

and when cool, this arrangement of spokes and naves is ready to be inserted within the tire, the inner diameter of which is too small for the purpose until, by heating and stretching, it becomes adapted thereto.

Digitized by Google

The tire being taken out of the ring furnace, is put into what is called a *stretching machine*, in which a number of blocks forming segments of the circle required are thrust out by means of an hydraulic press, so as to stretch the red-hot tire to the size sufficient to allow the arrangement of spokes and nave to drop in. This being done, the tire is left to cool, and in doing so closes in upon the spokes, binding and compressing them firmly into one compact system, and a rivet through each spoke into the tire completes the operation.

PLANING IRON.

THE demand which has been excited within the last half century for such beautiful and accurate machines as the steam engine, cotton spinning apparatus, and indeed most of the machinery required by the factory system, has been supplied chiefly by the invention and perfecting of *machines for producing machinery*—mechanical contrivances superseding the human hand, and more than supplying its place in holding, applying, and directing the motions of cutting tools to the surface of the work to be turned, planed, or otherwise cut into the six primitive or elementary geometrical figures to which all the forms met with in machines may be reduced—namely—the *line*, the *plane*, the *circle*, the *cylinder*, the *cone*, and the *sphere*.

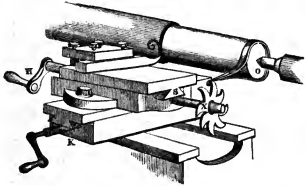
Among all the contrivances seen in operation in an engineer's workshop, the SLIDE REST occupies the most important position. Before its introduction "nearly every part of a machine had to be made and finished to its required form by mere manual labour; that is, on the dexterity of the *hand* of the workman, and the correctness of his *eye*, had we entirely to depend for accuracy and precision in the execution of such machinery as was then required; consequently the enormous expense which was incurred in such attempts, even in the production of comparatively simple machines, in most cases proved a formidable barrier to the supply of such as the increasing wants of civilization rendered desirable: and when at length the successful efforts of Watt and Arkwright produced such an entire revolution in the steam engine and cotton manufacture, and so disclosed to mankind such vast mines of wealth in the latent powers of production, and capabilities of every country, and as the only obstacle in realizing them consisted in an almost entire dependence upon manual dexterity for the formation and production of such machines as were required, the necessity of more trustworthy and productive agents rendered some change in the system imperative. In short, a sudden demand for machinery of unwonted accuracy arose, while the stock of workmen then existing was neither adequate in respect to number or ability to meet the wants of the time; and but for the introduction of the slide rest principle, we never could have attained to one thousandth part of the bright objects which were then disclosed to view, and which have since been so wonderfully and amply realized."*

"The steam engine itself," (continues the same writer,) "which supplies us with such unbounded power, owes its present perfection to this admirable means of giving to metallic objects the most precise and perfect geometrical forms. How could we, for instance, have good steam engines, if we had not the means of boring out a true cylinder, or turning a true piston rod, or planing a valve face? It is this alone which has furnished us with the means of carrying into practice the accumulated results of scientific investigation in mechanical subjects."

---

* Nasmyth on Tools and Machines.

Before the introduction of the slide rest, the workman had no other means of applying and guiding his tool to the work in the lathe, than his unaided muscular strength; and the exertion required in turning iron was so great, that he soon became exhausted, and his work varied with his declining strength. Occasionally he could not avoid cutting too deep, which would compel him either to go over his work again, or to leave the mark of his tool in the metal. By this means, therefore, true work could not be ensured. If, however, instead of working the tool by hand, it were by some mechanical contrivance held firmly to the work, and while cutting a shaving from the bar in the lathe, the tool were slid gently along, it is evident the bar would be turned quite true. On reference to the following figure, it will be seen that these objects are attained by the slide rest. Here the tool is held firmly by a sort of iron hand or vice, which is made to move in the required direction by means of the slide S, the sliding motion being given by the workman turning the screw handle H, the depth of the cut being regulated by the under slide K, also moved by a screw handle.

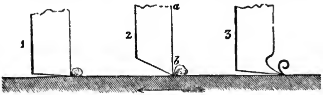


THE SLIDE REST.

By the separate or combined motion of these two slides, the tool can be made to act along or across the work with perfect accuracy, the business of the workman being confined to turning the screw handle H, and even this slight duty may be dispensed with and the machine made self-acting, by attaching a star x to the wheel H, and an iron finger to the end of the work in the lathe at O. Now it is evident that for every revolution of the work, the finger fixed round O will bear down one of the points of the star x, the effect of which is the same as turning the screw handle H, whereby the tool is moved along the surface of the work.*

The application of the slide rest principle in the engineer's workshop is very extensive; but it will be sufficient for the purposes of the present treatise to give one more illustration of its importance, and the one perhaps most in use is the PLANING MACHINE, which is nothing more than the application to plane surfaces of the slide rest as above explained for cylindrical forms.

In arranging the planing machine, it is of importance to consider the *direction* in which the metal is to be cut or penetrated. Suppose the shaded portion in the following engraving to be a surface of iron, from which it is desired to cut off shavings, either by moving the iron against the tool in the direction of the arrow, or by moving the tool over the surface of the iron in a contrary direction. If a tool of the form given in No. 1 were employed, the



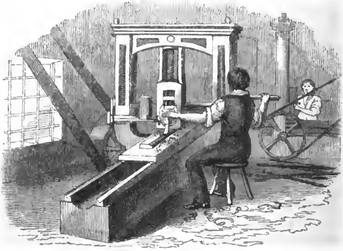
metal would not be cut; its particles would only be rubbed or crushed off by sheer force, because the cutting edge is so very blunt that it forms a right angle with the face of the iron, and the whole force is expended in merely rubbing off, not cutting, the metal. In No. 2 the same objection applies with even greater force; for not only does the tool act at right angles to the surface to be cut, but its form gives it a penetrating action in the direction *a b*, which would produce a number of teeth-like marks more or less deep, according to the strength of the cut and that of the tool. In No. 3, however, the cutting edge is in the direction of the strain or cut; and this edge is also arranged with reference to the greatest strength, the mass of metal behind the edge giving it firmness and support. The shavings are turned off in the form of curls without any tendency to chatter or produce a rippled surface. The defects and merits of the three forms of tool are thus summed up by Mr. Nasmyth:—In No. 1 we have strength, but no acuteness in either direction. In No. 2 we have acuteness, but in a direction quite opposite to that in which we require it, and no strength. In No. 3 we have acuteness entirely in the direction in which we require it, and the greatest degree of strength. These examples illustrate the principle to be attended to in forming and setting a tool to cut any surface; namely, the end of the tool must be so placed as to form the least possible angle with the surface to be cut.

---

* According to Mr. Nasmyth, the honour of the invention of the slide rest is due to the late Henry Maudslay.

IRON SHAVING.

In the planing machine the work to be cut is firmly bolted to a table sliding in dove-tailed grooves, and travelling backwards and forwards under the cutting tool, which is held firmly in a slide rest capable of being lowered and adjusted so as to cause the tool to cut more or less deeply. When one end of the work has escaped from under the tool, the table is shifted back, and the slide rest moved a little way across the table, so as to take off the next shaving close to the one previously cut. Thus by a series of slidings of the table backwards and forwards, the tool is made to go over the whole surface of the work, so as to render every part equally smooth. It is necessary to keep the tool cool during this operation, or it would soon become soft; for this purpose water in a small vessel is arranged so as to drop upon the cutting edge; the heat produced is sufficient to boil the water, which passes off in the form of steam.



PLANING MACHINE.

THE

MANUFACTURE OF NAILS AND SCREWS.

NAIL-MAKING is one of those domestic employments which have not been entirely superseded by the factory system. In passing through the villages in the environs of Birmingham, and seeing the number of diminutive forges attached to the cottages, and females young and old wielding the forge hammer, the writer was forcibly reminded of the description of William Hutton, the historian of Birmingham, which, though written a century ago, is still applicable. "The art of nail-making," he says, "is the most ancient among us. We may safely charge its antiquity with four figures. We cannot consider it a trade *in*, so much as *of* Birmingham; for we have but few nail-makers left in the town: our nailers are chiefly masters, and rather opulent. The manufacturers are so scattered round the country, that we cannot travel far in any direction out of the sound of the nail-hammer. But Birmingham, like a powerful magnet, draws the produce of the anvil to herself. When I first approached Birmingham from Walsall, in 1741, I was surprised at the prodigious number of blacksmiths' shops upon the road; and could not conceive how a country, though populous, could support so many people of the same occupation." In some of these shops, Hutton observed one or more females wielding the hammer, and being struck with the novelty, inquired "whether the ladies in this country shod horses?" but was answered, with a smile, "They are nailers."

Digitized by Google

The nails produced at these small establishments are called *wrought* nails, to distinguish them from those which are *cast* in moulds, or *cut* or punched out of plates of iron by machinery. Wrought nails are also made from plates rolled for the purpose, and afterwards split by means of slitting rollers into rods, called *nail-rods* or *split-rods*, of various sizes and qualities, according to the variety of nail required. It was calculated some years ago, that in the neighbourhood of Birmingham alone upwards of sixty thousand persons, men, women, and children, were occupied in nail-making; and that many of the iron works in the same district furnished from one to two hundred tons of split iron rods weekly.

The quality of iron used in forging nails is more or less refined or tough, according to the sort of nail to be made. "The very best quality is employed for horse-shoe nails, to admit of their being drawn out very fine, and prevent their breaking in the hoof. Wheelwrights' nails, which are forcibly nailed against the iron tire, and the clouts, also require the metal to be very tough. In like manner, hurdle-nails require good iron, that the points may clench soundly, and their broad heads not be broken off. The finer or smaller kind of nails, being much drawn under the hammer, must also be of good iron; and, indeed, all such where great stability is of essential importance."*

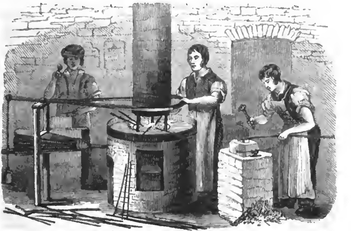
Although the quantity of nails cut or punched by machinery is enormous, and a preference is given to them in some cases on account of their uniformity and cheapness, yet there is still a very large demand for forged nails, of which there are no less than three hundred different *sorts*, each sort having at least ten different sizes. The workpeople engaged in forging nails, or *nailers*, as they are called, subdivide their work in such a way that each individual confines himself to a peculiar *sort* of nails, and thus acquires a degree of skill and rapidity of production which is often very remarkable.

---

* Hebert. Engineers' Encyclopædia.

The apparatus required by the nailer is simple. It consists of a small hearth or forge for bringing the iron to the proper heat; an anvil, a hammer, and one or two other tools which will be noticed presently.

A most convenient and economical forge is that patented some years ago by Mr. Sperne, of Belper, near Derby. It is circular in form; the advantage of which is, that five or six persons may conveniently work at it at the same time. Its construction, and the arrangement of the bellows, &c. will be understood from the following figure. The brickwork is first carried up in a cylindrical form to the height of twenty-four inches, leaving proper openings for the delivery of the ashes, the reception of the water troughs, and for the insertion of the nozzle of the bellows. The circular aperture in the centre is then



NAIL FORGE.

covered with a fine cast-iron grating, which forms the bottom of the furnace. The courses of brickwork are next carried up a foot higher, and the whole is then surmounted by a cast-iron plate, with a rim or border, forming a convenient dish for holding the fuel to replenish the fire. In the centre of the cast-iron top plate is an opening corresponding with the fireplace, and to this opening is fitted an iron ring, supporting on three iron pillars another ring, which carries the brickwork of the chimney, The bellows are suspended from a frame, and are worked by a lever which encircles the chimney, affording every workman employed the convenience of acting upon it with facility; and as this forge will accommodate six nailers, the fire is always kept bright by the continual motion of the bellows.

After describing the construction of his forge, the inventor remarks:—" There are many novel features in this invention, which do not strike the reader on the first perusal. Nothing is represented to his mind but bricks, mortar, and iron in the form of a forge; with which substances forges have been erected since the days of Tubal: while, to the operative man, who has to preserve the quality of pure iron uninjured, this invention presents a most valuable acquisition. In no other forge (excepting a hollow fire) can pure wood charcoal be used; no other forge is constructed without a back; no other forge has a grating to keep the fire clear and prevent the accumulation of clinker; no other forge will admit of the same number of workmen being employed at the same time; no other forge can be erected at so little expense." The use of wood charcoal is an advantage in this over other forges: for, " by a mixture of wood charcoal with coke for fuel, the metals to be wrought will acquire a surprising degree of malleability, and weld with great ease; their tenacity and clearness will also be improved, and they will have, when cold, a better face or skin than could be put upon them by any other method."

The anvil used in forging nails is a small cube of steel fixed to a heavy iron block, which is surrounded with stones and imbedded in smithy-slack, so that the small anvil only is seen. The size of the hammer depends upon that of the nails to be forged, and is similar in shape to the hammer used in cutting files, a figure of which is given at page 25 of "The Manufacture of Files and Saws." The face of this hammer is inclined or sloped considerably towards the handle; and "the degree of this obliquity, the weight of the hammer head, the size and shape of the handle, &c. are matters of nice consideration; one nailer being rarely able to work comfortably with another man's hammer: hence, as they are somewhat given to tramping from place to place, each workman generally carries with him a favourite hammer, which, like the fabled mallet of Thor, is both the symbol and the agent of the owner's power."*

At the commencement of his work the nailer puts into the fire the ends of three or four nail-rods, and works the bellows so as to bring them to the proper heat. This being attained, he takes one out of the fire, and resting it on the anvil, proceeds to draw out the nail by a few blows skilfully applied. He then cuts off the end, thus forged, by means of a chisel, called a *hack-iron*. A little way from the cutting edge of this chisel is a stop or check, which the point of the nail is made to touch so as to determine its length; then, striking a single blow on that part which rests upon the edge, the length of the nail is thus determined. If the nails are of moderate size, the rod is still sufficiently hot to allow another nail to be forged and cut off: but if of large size, the rod must be returned to the fire after the first nail is formed. While the rod is being heated again, the nailer forms the heads of those just cut off, for which purpose he employs a tool called a *bore:* this is a piece of strong iron, ten or twelve inches long, furnished at each end with a steel knob perforated to the size of the shank or collar of the nail, and countersunk, so as to correspond with the head. Taking up the nail, still red hot, with a pair of tweezers and inserting it point downwards into the bore, the nailer strikes it with the hammer upon the projecting end, which forces it to take the shape of the perforation. The various shapes which are given to the heads of nails are produced by using bores differently perforated.

---

* Cabinet Cyclopædia.

The process of forging a nail is conducted with remarkable quickness and dexterity; and to give the reader some idea of what can be done by an experienced nailer, the following case, which occurred some years ago, may be instanced. James Leighton, a nailsmith of Stirling, undertook, for a trifling bet, to make 17,000 double-flooring nails, 1,200 to a 1,000, of 20lbs. weight, for two successive weeks; a task which seems scarcely credible. The workman, however, finished his first week's task by three o'clock on Saturday afternoon; resumed his labour on Monday morning, and concluded his second week's task with even more ease than he did the first. Allowing twenty-five strokes of the hammer (which is 2lbs. weight) to each nail, including the cutting of the rods into a size convenient to be handled, and reuniting them when too short, there were no less than 1,033,656 strokes required before the task could be completed. In addition to this, the workman had to give from one to three blasts with his bellows for every nail he made, had to supply the fire with fuel, and had to move from the fireplace to where the nails were made, and back again, upwards of 42,836 times. This man was in his fifty-first year, and had been a nailer from the age of nine years.

It has been already stated that there are about three hundred varieties or *sorts* of forged nails. The forms of these are known by certain specific names, which for the most part express the uses to which they are applied; as *hurdle, pail, deck, scupper, mop,* &c.; but there are other nails which are distinguished by the form of their heads, as *rose, clasp, diamond,* &c.; while others are known by the form of their points, as *flat, sharp, spear,* &c. The thickness of any specified form is expressed by the terms *fine, bastard, strong.* The length of some kind of nails is expressed by their lineal measure, but more commonly by the number of them required to weigh a pound or an ounce. Thus the term "7lb. rose" implies a rose-headed nail, with a sharp point, measuring about an inch and a half in length, and of which about a thousand weigh a pound. Rose nails, however, are made of about thirty different sizes, from 1½lbs. to 40lbs. per thousand; and taking the various sizes of other nails (which are not so numerous), the average number of sizes of each sort may be reckoned at ten, which multiplied by the number of sorts, which is equal to 300, makes 3,000 distinctive names to nails, all of which are immediately and precisely understood in the trade. The terms employed by retailers of *fourpenny, sixpenny, tenpenny,* &c. are very undefined as respects the kind, as well as the precise size, these varying with the locality wherein they are sold.*

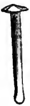
The following are some of the principal forms of nails, without reference to their size: the remarks which accompany them are abridged from the useful work just quoted:—

1.

1. The kind called *rose sharp* are extensively used for coopering, fencing, and various coarse purposes in which hard wood is used. A thinner sort, called *fine rose,* are used in pine and other soft woods, their broad spreading heads being calculated to hold the work down.

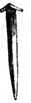
---

* Hebert.

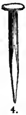


2.

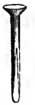
2. The *rose*, with *flat* or *chisel* points, is used where the wood is in danger of being split by the driving in of sharp points, which act as wedges; while those with flat points, being driven with their edges across the grain, prevent the splitting and hold faster.



3. *Clasp* nails are commonly used by house-carpenters in deal and similar woods: their heads, projecting downwards, stick into the wood and clasp it together, and when driven below the surface, allow a plane to pass over them.

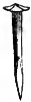


4.



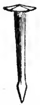
5.

4. *Clout* nails are used for nailing iron work and various substances to wood: they have a flat circular head, round shanks, and sharp points. The *counterclout* (5) have countersinks under their heads, and chisel points, and are much used by wheelwrights and smiths.

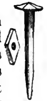


6.

6. *Fine dog* is distinguished from a thicker nail, called *strong* or *weighty dog*. They are also used for nailing down stout iron work, and for various other purposes where the heads (which are very solid, and slightly countersunk) are not required to lie flush with the work; their shanks are round drawn, and their points speared, which adapts them for piercing and clenching well.



7.

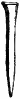


8.

7. The *Kent-hurdle* has a broad, thinnish rose-head, a clean drawn flat shank, and a good spear-point, well adapted for nailing and clenching the oaken bars of hurdles together. *Gate nails* are similar in form.

8. *Rose-clench* is a sort much used in ship and boat-building. They are used in nailing on the wood sheathing, which is soft, and liable to split unless bored; and as the nails have no points, the ends being left square, they punch out their own holes, driving

a portion of the wood before them, hold very fast, and render boring unnecessary. Hence they are much used in making packing-cases and boxes. The term *clench* is derived from the mode of employing them in boat-building, in which they are clenched either by hammering down the extremity, or by placing over it a little diamond-shaped plate of metal, called a *rove*, and rivetting the end of the clench nail down upon it, whereby the planks, &c. are firmly drawn together,



9.

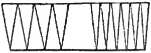
9. *Horse-nails*, in common use. Formerly the heads were made square, but the preference is now given to the countersunk, chiefly on account of their lying flush in the groove made for them, and more securely attaching the shoe to the hoof.

10.

10. *Brads* form a large class of very useful nails. *Tacks* are also a very numerous and useful class of nails. The chief place of manufacture for them and other very small kinds is Bromsgrove in Worcestershire, where it is a common feat of the workpeople to forge a thousand (1,200) tacks so small as to fill the barrel of an ordinary goose-quill, their weight being only about twenty grains.

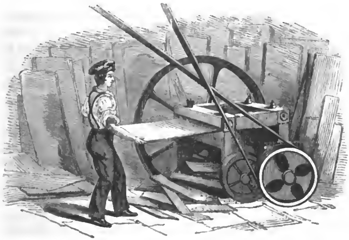
Cast-iron nails, from their great brittleness, are not extensively used; but their great cheapness recommends them for such coarse purposes as the lathing of plasterers, garden walls, stout shoes and boots, &c. The brittleness of cast-iron nails is partially removed by annealing, Cast nails of superior quality are also manufactured out of what is called " malleable cast-iron," a pure kind of iron, deprived of the greater part of its carbon by a process of annealing; by this process, however, the metal is rendered almost as soft as copper, and therefore quite unfit for most of the purposes to which nails are applied. In order to obviate the defects of cast-iron nails, and to produce them at a cheaper rate than wrought or forged nails, they are now extensively manufactured by cutting or punching them out of sheets of wrought iron.

The reader will understand the principle upon which nails are cut by the following illustration. If we take a slip or riband of paper half an inch wide, and of any length, and with a pair of scissors cut from the end triangular sections in the form of fine wedges, turning the paper over after every cut, in order that the head or broader part of every clipping may be taken from the point of the preceding one, and *vice versâ*, we shall get the form of that description of shoe-nail called a *sparrable* or *sparrow-bill*, from its resemblance to the mandible of a well-known bird. If the following cut represent the slip of paper, the stronger



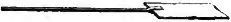
sections will represent sparrables, and the slighter sections *sprigs*, also used by shoemakers, and other workmen. If instead of this slip of paper we take a slip or rand of iron, and instead of scissors the fly-press with its cutting punches be used, it will readily be understood how nails are manufactured. It would be easy to cut out from rolled iron, nails of almost any size and shape by means of stout shears, but the disadvantage would be that all the nails would be bent or curled, which is not the case with those cut by punches.

The iron from which the nails are to be cut is prepared at the rolling mill in sheets or plates of any required degree of thickness. These plates are cut up into strips of the required size by means of a powerful cutting press. The man holds the sheet horizontally, and the blade descends and cuts off a strip; the moment this is done, he pushes the sheet forward, and another strip is instantly severed. The width of the strips is regulated by a check or stop behind the blade.

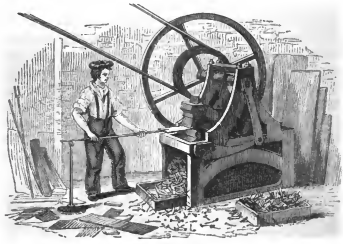


CUTTING ROLLED IRON INTO STRIPS.

- For the convenience of presenting these strips to the cutting press, they are mounted on a rod, as shown in the following figure. While one end of



the strip is being cut, the further end of the rod is supported on a forked rest, as shown in the next engraving, for the purpose of keeping the strip in its proper position. An ordinary form of punch, used in cutting the nails, consists of a cube of steel, the upper part of which is screwed in a kind of vice, and the lower part filed obliquely on the side, to the distance of about half an inch from the ends, forming a shoulder exactly the size and shape of the nail to be produced. The outer or cutting edge of this shoulder, which is formed by the vertical surface or front side of the punch, is made, by the motion of the machinery, to pass close by one of the edges of a four-sided bar of steel, hardened, and fastened across the bed in a horizontal position; so that the punch and this bar making right angles with each other, every descent of the former carries the groove in its vertical surface past the sharp square edge of the latter, and thus cuts off the amount of a nail from the end of the slip presented. As every cut, in consequence of the shape of the nail, leaves the end of the metal oblique, it is turned over after every stroke. The celerity with which this operation is performed would astonish a person unaccustomed to witness this kind of work. A nail-cutting machine has been formed with six cutters, each giving 160 strokes in a minute; so that when six slips are presented at once, each cutter chops off upwards of 900 in a minute; and as there are a large number of such machines in each factory, some idea may be formed of the prodigious quantity of nails manufactured daily in this country.*



CUTTING NAILS.

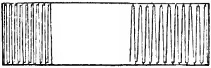
In another form of machine for cut brads, the cutting blade not only moves up and down, cutting out

---

* Cabinet Cyclopædia.

Google

a brad at each descent, but it also has a slight horizontal movement, first on one side and then on the other; so that the cuts being alternately oblique in different directions, the brads are formed without requiring the strip to be turned over after every cut. There is yet another form of machine in which the nail, after it is cut off from the strip, is instantly caught by a clasp and exposed to a strong pressure, whereby a head is produced much in the same way as was described in forging nails. The following figure will show that both brads and headed nails can be cut out of a flat strip of metal without any waste, simply by turning over the strip at each cut, so as to make the heads and points of contiguous nails fit into each other.



Before the nails are fit for use they require to be annealed, for which purpose they are put into close iron boxes, heated in ovens, and allowed to cool gradually. They are, lastly, packed in strong hempen bags, or made up in bundles or in casks, according to the market for which they are destined. By far the greater proportion of the vast quantities of nails manufactured are for home consumption, although there is a considerable trade to the colonies and to the East. The continent of Europe is chiefly supplied from Holland, of which Rotterdam is the great nail-mart.

The screw is a much more refined and recent invention than the nail; from its affinity to it, it is sometimes called the *screw-nail*, but more usually the *wood-screw*, from its common use by carpenters for fastening wood, or wood and metal, together. It is

Digitized by Google

a much neater fastening than the nail, and is applicable in numerous cases where, from delicacy of workmanship, a hammer could not be used.

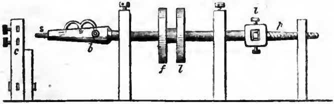
The blanks for screws were formerly forged by the nailers, these blanks being nearly the same as countersunk clout nails,* except that the ends are not pointed. The blanks were next made out of round rolled iron cut to the required lengths; the heads being formed by pinching them while red hot between a pair of dies, and the threads were cut by means of a file. But the method of making screws now most commonly adopted is that witnessed by the writer at a factory in Birmingham. Several rather complicated machines are concerned in the process. In the first, a coil of wire fit for making screws is arranged so that it can be drawn into the machine as it is wanted; pieces of the proper length are cut off, and one end of each struck up to form the head, and the blanks thus produced are then turned out into a box. By a second operation, the blanks are taken separately and placed in a lathe, where the heads and necks are properly shaped, by turning and cutting away the superfluous metal. Thirdly, the notch or nick in the head of the screw for receiving the screw-driver is cut by means of a circular saw; the woman puts each screw into a kind of clasp, which holds it firmly, and then, by means of a lever, raises it to the cutter; the nick is formed in an instant,—the clasp opens, the blank falls out, and another is inserted in its place, with great quickness. The teeth of the circular saws used in this operation, require filing up after every half hour's work: for which purpose they are taken out, softened by heating and slowly cooling, then filed and sharpened, next hardened by heating and suddenly cooling; after which they are again fit for use. Fourthly, the blanks are ready for *worming*, as the operation of cutting the thread is called. This is done in a lathe; and as the blank requires to be held therein very steadily, the nick

---

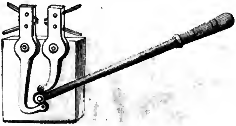
* See Fig. 5, p. 42.

CUTTING THE NICK.

just formed is made to assist in doing so. The arrangement is as follows:—A steel spindle or mandril revolves between collars in two uprights, by the motion of a strap passing round the pulley, *f*; *l* is a



loose pulley to carry the strap when it is required to stop the machine. At *i* is an iron box made to hold firmly the regulating screw, *p*. This screw is five or six inches in length, and is an exact pattern of the thread of the screw to be cut, so that a fresh pattern or regulating screw is required for every variety of screw. The screw to be cut, *s*, is fixed in an iron chuck or holder, *b*, and is held firmly by a kind of hasp, the nick of the screw resting against a chisel spike, and the shank projecting. The cutters are arranged in the frames at *c:* they are four in number, but only two are used in cutting the thread: they are shown on a larger scale in the following figure. These frames move on joint pins, and by

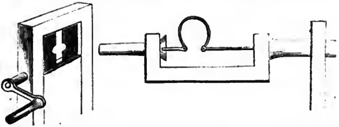


the operation of the lever the cutters are made to act upon the shank of the screw, and to exert a greater or less degree of pressure, according to circumstances. There is also a lever which causes certain directing points, resembling the cutters, to close upon the regulating screw, *p*, and the two levers being connected by a horizontal bar, can be depressed or raised together, and the cutters and directors applied at the same moment. In this way the inclination of the thread is determined by the pattern screw, and its shape by the form and position of the cutters.

This arrangement being understood, the order of proceeding is as follows:—The workwoman fixes a blank in the chuck; she next transfers the strap from the loose to the fixed pulley, thereby causing the chuck to revolve; she then depresses the levers, and the guides, acting upon the regulator screw from behind, cause the chuck to move forward and force the shank of the blank screw between the cutters, which turn out a shaving of metal, leaving a sharp thread or worm. The heat occasioned by this operation would soon destroy the temper of the steel cutters were they not kept cool; for this purpose, while the woman holds the lever down with one hand, she takes up with the other a piece of wood, dips it in water, and applies it to the tools. When the thread is traced far enough, the levers are raised, the chuck falls back, and the screw is released. Another screw is inserted in its place, and thus the cutting or tapping proceeds.

CUTTING THE WORM.

A form of screw, called, from its shape, the *gimlet-pointed*, patented by Mr. Ryland, of Birmingham, is cut by a somewhat different process. Instead of cutters, dies are used, and they are arranged in a vertical position as in the following sketch. They are opened and shut by a right and

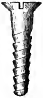


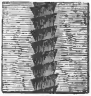
left-handed screw. As the dies regulate the size of the thread, there is no pattern screw, and of course the dies require to be changed for every variety of screw intended to be cut. The gimlet-pointed screw enters the wood easily and retains its

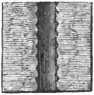
Digitized by Google

hold firmly, and it is not liable to break where the thread ends, which the common screw will often do, especially in hard wood.

Mr. Nettlefold's patent screws are also made on a similar principle. In them great attention is paid to the thread, the upper side of which is very flat or inclined, which causes a great resistance to its being forcibly pulled out of the wood; while the under side is considerably inclined, which enables it to go into the wood with great ease, and rendering it unnecessary, in soft elastic woods, to bore a hole for its reception. The form of this screw and its action upon the wood will be better understood from the following figures,


1


2


3

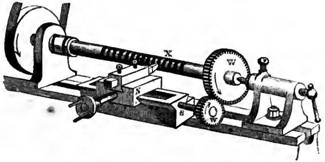
in which No. 1 represents the screw; No. 2 the mould made by it in wood; and the figure No. 3 is a section of the common form of screw, in which the worm is shallow and imperfect. "The chief defects of common wood screws, besides bad threads, are the having, at the termination of the worm, a projecting bur, which is apt to tear away the wood before it, and leave little or no solid matter for the screw to hold by; the nicks in the heads being too shallow, or highest in the middle, preventing the screw-driver from taking an efficient hold to turn them in and out."

Female or interior screws are usually cut with steel taps of the various sizes required. A steel tap is a screw from which a great part of the worm has been removed, by filing several flat faces along its whole length, the angles thus left forming a series of cutters.

The large iron screws used in vices, presses, &c.

Digitized by Google

were formerly made in dies turned with long levers, the thread being produced by indenting and squeezing up the metal. This rude method, so injurious to the stability of the screw, has been superseded by the elegant and scientific screw-cutting machine,



SCREW-CUTTING MACHINE.

which consists simply of a slide rest S, " whose toolholder is slid along by means of the screw S, which receives its motion from the work in the lathe by means of the wheels WW; by which it is evident, that, as the work X revolves in the lathe, a revolving motion will be transferred to the screw S, and the point of the tool will, on sliding along, leave a spiral or screw on the work; and according to the respective diameters of the wheels WW, so shall we have a screw formed on X more or less fine in the pitch of the thread, according to the proportions of the respective diameters of the wheels WW." The diameter of the wheel on the work is twice the diameter of that at the end of the slide screw. " The pitch of the thread on X will, therefore, be twice as wide as on S; and as S and X are revolving in opposite directions, we shall have a right-hand screw on the one, and a left-hand screw on the other, or the reverse, according to the nature of the guide-screw S."* The depth of the cut is made by passing the tool several times along the groove, setting it deeper each time by means of the adjusting screw N.

---

* Nasmyth on Tools.

MANUFACTURE OF GUN-BARRELS.

Birmingham is the seat of the gun-trade, and its introduction and establishment in this town are stated by Hutton in the following terms:—

"Tradition tells that King William was once lamenting that guns were not manufactured in his own dominions, but that he was obliged to procure them from Holland, at a great expense, and with greater difficulty. Sir Richard Newdigate, one of the members for the county, being present, told the king 'that genius resided in Warwickshire, and that he thought his constituents would answer his Majesty's wishes.' The king was pleased with the remark, and the member posted to Birmingham. Upon application to a person in Digbeth,* whose name I have forgotten, the pattern was executed with precision, and when presented to the royal board, gave entire satisfaction. Orders were immediately issued for large numbers, which have been so frequently repeated, that they never lost their road; and the ingenious artists have been so amply rewarded, that they have rolled in their carriages to this day. Thus the same instrument which is death to one man is genteel life to another."

The manufacture of fire-arms is a remarkable example of the subdivision of labour. On referring to a Birmingham directory we get some idea of the number of trades concerned therein. Thus we have the gun-barrel maker, gun-barrel filer and smoother, gun-barrel bronzer; the gun-lock and furniture forger and filer; the tip maker and breech borer;

---

* A district or parish of Birmingham.

the welder and rubber; the rib forger; the gun furniture polisher; the gun-stock maker; the bayonet and ramrod maker; the percussioner; the gun-flint dealer; the gunpowder flask and shot charger, and shot-belt maker; and the brassfounder. In addition to this list (which is by no means complete) we have the gun finisher, or gunmaker, who collects all the parts of the article, and puts them together just as a watchmaker combines in one machine the various works which are made by different workmen.

To trace the great variety of processes concerned in the manufacture of a musket is not the object of this treatise. As an illustration of manufactures in iron, the gun-barrel is the only part which need engage the reader's attention. The processes concerned in it are curious, and the means taken to ensure sound workmanship are of great interest.

The iron used in the manufacture of gun-barrels is received at the forge in the form of long narrow ribands, either flat or half-round. These are broken into short pieces, and made up into a faggot, by placing on a table first five or six pieces of the same length side by side, then crossing these with a second layer of short pieces at right angles; then using longer pieces for the third layer in the same direction as the first; then crossing these with shorter pieces, and so on until a faggot or *brick*, as the workmen call it, of the required size is built up. A number of these bricks are put into a wind furnace and raised to the welding heat, sand being occasionally thrown over them to prevent the iron from burning. They are taken out one at a time, and placed under a shingling hammer, where all the separate strips are consolidated into one mass.

The lump of iron thus formed is next flattened out between rollers, and clipped with shears into the form of a plate, called a *skelp*, of the proper size for a gun-barrel. The thicker end of the skelp being heated to redness, is placed over a hollow in the face of the anvil; the sides are turned up with the edge of the hammer, and an iron mandril or rod inserted, over which the skelp is gradually moulded, the edges being firmly united, so as to form a compact tube of iron. Of course the mandril has to be withdrawn and the skelp heated many times before the barrel is completely forged. This method, however, has been to a great extent superseded by the use of grooved rollers, the grooves being cut in such a manner as to receive the plate of metal previously turned over upon the mandril when four inches in diameter through its whole length, and yet to produce a skelp gradually tapering from that width to two inches and a half at the other end. Skelps formed in this way are more free from flaws than the hammered ones; the compression of the rollers producing more perfect cohesion among the metallic particles, and uniting the edges so perfectly that the seam is not visible when the barrel is ground.

Another method of forming barrels is curious. The iron used for the purpose is of tough and excellent quality, and rolled in the form of square bars. The end of a bar being made red hot, is curled or twisted in a spiral form round a mandril of the size and shape of the intended barrel. Four bars are generally used to make a barrel of the ordinary length, which is from thirty-two to thirty-eight inches, and the two which form the breach or strongest part are much thicker than those used in making the muzzle or fore part. The turns of the spiral are united in small portions by bringing them to a white heat, and striking the end of the coil several times against the anvil with considerable force. This is called *jumping* the barrel, and by this means the edges of the metal are driven together. A mandril is then introduced into the spiral, and the heated portion lightly hammered in order to flatten the ridges or burs raised by the jumping. When

Digitized by Google

these twisted barrels are finished they have a very beautiful appearance, and are also said to be but little liable to burst.

When the barrel leaves the welding shop it is carefully examined by being filled with water, whereby any crack extending through the substance of the metal is detected and closed by re-welding. The barrel is set perfectly straight by a few blows of a hammer upon an anvil, and is then transferred to the boring mill. The boring instrument is a steel drill placed horizontally in a chuck in connexion with the moving power; the barrel is also fastened horizontally, and its tube is pushed forward by means of a regulated lever, so that the drill may gradually enter it, and by its rapid rotation shave away enough of the metal to form a tolerably smooth surface on the interior of the tube. It is finished by the subsequent process of *fine boring*. The heat excited by the friction of the drill is kept down by a stream of cold water constantly flowing on the barrel.

The outside of the barrel has next to be smoothed by grinding upon large stones about six feet in diameter, and about eighteen inches across the face. The grinder, seated upon a wooden horse, presses every part of the barrel in succession against the stone, allowing it to roll slowly through his hands. Some manufacturers, however, prefer turning the barrel at a lathe, a number of steel cutters being made to work successively upon its surface. One advantage of this method is said to be greater equality in the barrels, whereas, in those which are ground, one side of the barrel is often much thicker than the other. In the factory visited by the writer at Birmingham, grindstones were used: they were collected in a gloomy shed, and the appearance of the grinders was striking, hovering as they were over the ponderous stones in rapid rotation, their faces brightly, and the surrounding objects dimly, lighted up by the stream of sparks issuing from each wheel.

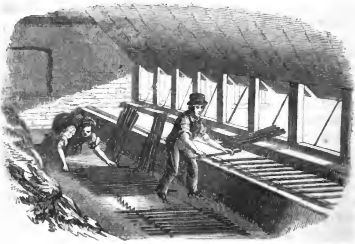
Fine boring is the next operation, for which purpose the drill called a *rounder* is used; and as much less force is required and less heat excited than in rough boring, the barrel is pressed against the borer by means of a weighted rope passing over a pulley; and no water is used for cooling the barrel.

The barrel is next tapped at the stouter end, and fitted with the breech screw. It is now ready for proving: that is, it is loaded with a much higher charge of powder than it is ever intended to bear; and if this is fired without bursting, the barrel is declared fit for service. All fire-arms manufactured in Birmingham and its neighbourhood are required to be thus proved under a penalty of 20*l.*

The proof-house was erected more than fifty years ago under the sanction of Government: wardens and a proof-master were appointed chiefly from among the gunmakers themselves, and permission was granted to stamp on the guns approved by them the royal arms, with the letters B. P. V., that is "Birmingham Proof Viewed." The object of this arrangement is to secure the public from the lamentable accidents likely to arise from the use of ill-made and defective gun-barrels, and also to maintain the reputation which Birmingham has so long enjoyed over the greater part of the civilized world for this peculiar manufacture. The barrels of guns intended for the public service are proved at a separate establishment maintained entirely by Government.

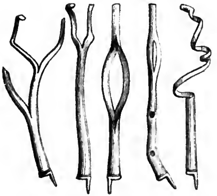
The Birmingham Proof-house is situated in Banbury-street, in the south-east division of the town. The building is somewhat extensive, and is separated into several distinct compartments. Within an inner court-yard is the gunpowder magazine, a small but massive stone building standing by itself: beyond this is a room for casting bullets. These are cast in long moulds formed of two parts, containing, when closed, a series of hollow spheres connected by a long channel, along which the melted lead flows, and shorter channels into each sphere, so that the bullets are turned out in the form here shown, and are separated from the pipe and stems by a pair of nippers, with cutting edges adapted to the surface of the bullet. Another department is appropriated to loading the barrels with powder and ball. The charge is regulated according to the weight and calibre of the barrel, a scale of printed regulations for the purpose being fixed up in the room. A measure filled with the gunpowder, containing three or four times the quantity which the barrel will afterwards have to bear, is poured in by means of a funnel, and well rammed down with a heavy copper ramrod; then the bullet, which exactly fits the barrel, is driven home, no wadding being used. A number of barrels being thus prepared, are taken to the firing-house, which is a low detached shed furnished with falling wooden shutters at the side, and ventilating openings just under the roof. On one side, near the ground, is a sort of frame-work for supporting the barrels to the number of 129, in two rows, one above the other. They are placed about six inches apart, and point to the opposite dead wall, against which is piled a quantity of earth and sand for receiving the balls. When the barrels are arranged, a train of powder is made to connect all the touch-holes. The wooden shutters are closed; the doors locked; and a man with a long rod heated at one end fires the train through a hole in one end of the walls left for the purpose. The noise of the explosion is very remarkable, forming as it does a succession of loud sharp reports, lasting several seconds, and resembling a peal of thunder. This is easily to be accounted for; for however rapid may be the explosion of gunpowder, the fire has to travel the whole length of the train, diverging a hundred and twenty-nine times from a right line, in order to fire the guns; the time occupied herein

occasions each gun to give a distinct report, which, being instantly followed by the report of the next



INTERIOR OF PROOF-HOUSE.

gun, produces the rattle or continuous peal referred to. The explosion being ended, a few minutes are allowed to elapse before the men enter to remove the guns, because a barrel occasionally *hangs fire*, and may explode in the act of being removed. The shutters being thrown up and the doors opened, the smoke rushes out in clouds, and the appearance of the barrels is not a little extraordinary. It is scarcely to be supposed that in so large a number some should not be faulty; the defects are so well known as to obtain for them their appropriate names. A few may have a *chink* or small rent in the direction of the length of the barrel; others may have a *crack* across it; while others again may have a *flaw*, which is a small pit or hollow in the metal. In any one of these cases the barrel is likely to burst in proving, and is whirled out of the frame to a distant part of the shed. The writer has collected some of the forms of the burst barrels in the following sketches. In



GUN-BARRELS BURST IN PROVING.

examining a large number of them at the proof-house, he was surprised to notice several perforated as if with a bullet in the very act of proving; and such indeed they were. But how could this happen if the barrels are all ranged side by side? It has been already stated that an appreciable amount of time is occupied in the firing of a row of guns, and that when a barrel bursts it is whirled by the force of the expanding gases and by the recoil out of its frame to a distant part of the shed. Now let us suppose that sixty barrels are arranged in one row and fired by a train, and that the fifth in the row is faulty: this will burst, and in doing so be whirled out of its frame to a distant part of the shed; in its passage thither it may meet the shot of one of the guns in advance of the position it occupied in the row, in the very act of firing; such, for example, as the fortieth or fiftieth gun; and as this shot is urged by a triple or quadruple charge of powder, it would easily pass through the metal if it struck it favourably.

After the guns are removed from the firing-house, they are required to be left untouched for four-and-twenty hours, after which they are washed out in a trough with warm water, and dried with tow. The viewer then carefully examines them, and hands such as are sound to the stamper, who attaches the proof-mark. The unsound ones are returned to the maker, and the workmen have to repair the defects of the unsound barrels at their own cost.

At the Government Proof-house at the time of the writer's visit, some barrels were being charged with 16 drachms of powder (only 4½ drachms being required for the gun in ordinary service); a wine-cork exactly fitting the barrel was then rammed down tight with a massive copper rod; the bullet was next put in, and another cork rammed upon that. Then each barrel was proved separately: for which purpose it was placed in a massive wooden chest, one end of which was left open for the escape of the bullet, which was fired as before into a pile of earth and sand. On closing the cover of this chest (which was nearly balanced by weights passing over a pulley), a spring was detached, which fired a percussion-cap and exploded the gun. In case of fracture, the chest protects the man from injury.

In some cases the barrels are subjected to even a more severe test than either of the above. The barrel is filled with water, and an air-tight bullet driven in. Water being nearly incompressible, but transmitting pressure in all directions, insinuates itself into the minutest chink or crack, and appears on the outside, thus showing where the barrel is defective.

The finishing processes of the barrel do not require much illustration. When intended to be bright, they are first filed all over with smooth files, and then burnished with a piece of hard polished steel. The task of keeping the barrel bright was found to be so fatiguing to the soldier, that the Duke of Wellington during his peninsular campaign allowed all musket-barrels to be *browned*, an effect produced by certain acid and other solutions.

The stock of the gun is commonly of walnut-wood, and is formed with a variety of tools for receiving the different parts of the gun. This, together with the brass, the trigger-guard, and other brass ornaments, are mostly formed by different workmen. The gun-lock is made at Wolverhampton, but all the other parts are made or prepared at Birmingham.

In order to give some idea of the wonderful extent of the gun-trade during the war, which terminated in 1815, it is stated, that at Birmingham a musket was made every minute; and that Birmingham could set up 200,000 stand of arms per annum, while London could produce from 80,000 to 100,000 in the same time. Since this statement was made, the peace of forty years' duration has been interrupted by the Crimean war and the Indian revolt, which showed among other deficiencies that the old form of musket was an inefficient weapon. It has accordingly been or is being superseded by the rifle, which is now manufactured in enormous quantities in Government workshops. Let us hope that by making the weapon more deadly, we diminish the chances of war. Let us pray that men may enter more deeply into the spirit of Christianity, and thus in some measure anticipate that happy time when "wars shall cease, and the knowledge of the Lord shall cover the earth as the waters cover the sea."

WIRE-DRAWING.

It is probable that the malleability of metals was discovered before their ductility; the process of hammering out a piece of metal into a thin plate or leaf, being more simple than first forming it into a rod and then drawing it out into a wire by passing it through a series of holes smaller than itself, in a plate of some harder metal. Beckmann thinks that wire was first made by cutting thin plates of metal into slips, and afterwards rounding them with a hammer and file; and this conjecture is borne out by the process adopted in making the sacerdotal dress of Aaron. "And they did beat the gold into thin plates, and cut it into wires, to work it in the blue, and in the purple, and in the scarlet, and in the fine linen, and cunning work."* Wire-work is rarely mentioned in the writings of the ancients, and whenever it is spoken of, it appears to have been prepared on the anvil. Even in comparatively modern times, there is evidence to show that the drawing-plate was not known. "As long as the work was performed by the hammer, the artists at Nuremberg were called *wire-smiths;* but after the invention of the drawing-iron, they were called *wire-drawers* (drahtzieher), and *wire-millers* (drahtmühler). Both these appellations occur in the History of Augsburg, so early as the year 1351; and in that of Nuremberg in 1360; so that, according to the best information I have been able to obtain, I must class the invention of the drawing-iron, or proper wire-drawing, among those of the fourteenth century." †

---

* Exodus xxxix. 3.

† Beckmann.

It is not known with certainty when the art of drawing wire was introduced into England. According to some accounts, wire was manufactured by hand until 1565, in which year one Christopher Schultz, a native of Annaberg, in Saxony, in company with some other foreigners, came to this country, under the permission granted by Queen Elizabeth to strangers, to dig for metallic ores, and introduced the drawing-plate. Previous to this, English iron wire was so little prized, that the supply was chiefly obtained from abroad, as were also the combs employed by the wool-combers. The home manufacture, however, improved rapidly, and in the reign of Charles I. it was encouraged by prohibiting the further importation of foreign wire. In a proclamation of 1630, it is stated, "that iron wire is a manufacture long practised in the realm, whereby many thousands of our subjects have long been employed; and that English wire is made of the toughest and best Osmond iron, a native commodity of this kingdom, and is much better than what comes from foreign parts, especially for making wool-cards, without which no good cloth can be made. And whereas complaints have been made by the wire-drawers of this kingdom, that by reason of the great quantities of foreign iron wire lately imported, our said subjects cannot be set on work; therefore, we prohibit the importation of foreign iron wire, and wool-cards made thereof, as also hooks and eyes, and other manufactures made of foreign wire. Neither shall any translate and trim up any old wool-cards, or sell the same at home or abroad."

During a long period, wire-drawing was carried on in the forest of Dean; but in the seventeenth century, it seems to have followed the woollen cloth manufacture into Yorkshire. Barnsley and its neighbourhood were long celebrated for the manufacture of wool-cards; but at the present day wire-drawing is carried on extensively throughout the manufacturing districts, although Birmingham has, perhaps, the largest share of the trade.

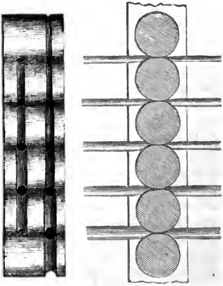
Before the invention of grooved rollers, rods of iron intended for the drawing mill were hammered out to the proper dimensions. The iron manufactured for the purpose was the best and toughest that could be procured from native ores, and was called *asteom* or *esteom* iron; or, as in the proclamation of Charles I., *Osmund* or *Orsmund* iron. It was wrought carefully under the hammer into rods about the thickness of the little finger, and after being well annealed, was sold in bundles to the wire-drawers under the above appellation. These rods were further reduced in size by an operation called *ripping* or *rumpling*. The machine by which this process was carried on is thus noticed by Beckmann:—"The greatest improvement ever made in this art was undoubtedly the invention of the large drawing machine, which is driven by water; and in which the axle-tree, by means of a lever, moves a pair of pincers, that open as they fall against the drawing-plate; lay hold of the wire, which is guided through a hole in the plates; shut as they are drawn back; and in that manner pull the wire along with them. What a pity that neither the inventor nor the time when this machine was invented is known. It is, however, more than probable, that it was first constructed at Nuremberg, by a person named Rudolf, who kept it long a secret, and by these means acquired a considerable fortune. Conrade Celtes, who wrote about the year 1491, is the only author at present known who confirms this information; and tells us that the son of the inventor, seduced by avaricious people, discovered to them the whole secret of the machinery; which so incensed his father, that he would have put him to death, had he not saved himself by flight."

Compared with modern apparatus, this machine is, of course, rude and inefficient, and does not require further notice in this place. In France, iron wire is called *fil d'Archal*, and also *fil de Richard*, from the name of the person, Richard Archal, who is said to have first invented or established the art of drawing iron wire in that country; but according to Menage, the term, *fil d'Archal* is derived from the latin word *filum* and *aurichalcum*.

In the modern process of wire-drawing, the iron or steel is usually prepared for the drawers by passing it through grooved rollers; the grooves gradually diminishing in size, so as to produce a rod of the required thickness. "There are few exhibitions of the effect of machinery upon metal, which are more striking to a stranger than the promptness and facility by which a slender string of iron [or steel] is spun, as it were, out of the stubborn bar. These rollers, which are generally at the least seven or eight inches in diameter, are sometimes made to perform 350 revolutions in a minute. A bar of steel, about one inch square, and thirty inches long, is drawn out of the heating furnace, at a strong red heat, and passed between these rollers eight times in less than a minute, during which it is elongated to from twenty to forty feet."* As these bars can only be rolled with facility at a bright red heat, and the metal cools quickly, various contrivances have been made to economise time; for example, a third roller has been added, so that the wire, on making its appearance from the upper cavity, is instantly caught and inserted in the under groove, by which means it is rolled and reduced, in both directions, without loss either of time or of heat. The following is an arrangement of six small rolls, the gear on their axis being so modified as to give every succeeding roller an opposite rotation, thus producing the effect of five pairs of rollers. The bar of steel being inserted between the first and second roller, its end is dexterously caught by the man on the other side with a pair of tongs, and pushed back through the second and third rollers; it is then passed between the third and fourth, and so on, till it is reduced to the proper size between the fifth and sixth rollers.

---

* Cabinet Cyclopædia.



STEEL ROLLERS.

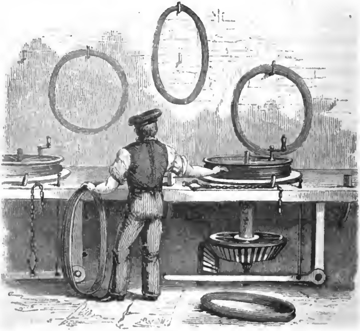
The steel rods thus prepared at the rolling mill are generally about the eighth of an inch in diameter; they are laid in coils, and subsequently sold to the wire-drawers, by whom they are reduced to smaller sizes. Cast steel wire, of which the best needles and some other articles are made, is still commonly tilted to about a quarter of an inch square, and afterwards rounded on the anvil, previously to its being passed through the drawing-plate.

When the coils of iron or steel are received by the wire-drawer, they are covered with oxide or rust, which forms in toughish scales in the process of rolling. This is removed by putting the coils into a large revolving cylinder, with coarse gravel and water: the friction of the stones and sand loosens the oxide, and the dashing of the water removes it.

The process of drawing out a great length of thin wire from a short rod of metal is a very gradual one. The rod is first forcibly dragged through a hole in the draw-plate a little smaller than itself, and as the metal in which this hole is formed is harder than the wire, the latter must yield and become extended in length: this lengthened wire is again passed through a hole, still smaller than itself, whereby it is again elongated; and so on for ten, twenty, or thirty holes, all gradually diminishing in diameter, until the proper size is obtained. The draw-plate is generally formed of the best cast steel, about six inches in length, and an inch and a half in diameter, and of a roundish or cucumber form, with the exception of one flat face. The holes through which the wire is drawn are formed by punching the flat side of the plate in a red-hot state, a number of punches, gradually dimishing in size, being employed for each hole, so as to make it of a tapering form.

The factory arrangements for wire-drawing will be understood from the following engraving, which represents a portion of a strong bench of timber or cast iron. In this bench are fixed the drawing-plates, in an upright position, and accompanying each plate is a cylinder, called by the workmen the *drawing-block*, the motion of which draws the wire through the plate, and winds it upon its rim. Motion is communicated to these blocks by means of a horizontal shaft of iron revolving either by steam or water power, and containing a number of mitre or bevel wheels which drive the upright shafts containing the blocks. Each block can be stopped in a moment by detaching it from the upright, by means of a lever worked by the foot: the top of each upright contains a cross, which fits into a corresponding cavity at the bottom of the block; so that when the lever is pressed by the foot, the block is simply lifted off the cross, and is at rest.

At the commencement of the operation, the workman points one end of the coil by making it red hot and hammering it to a point upon an anvil, so as to make it pass through a hole in the draw-plate. A pair of tongs or forceps, fixed to the bench, is then made to grasp the end of the wire, and pull it through the drawing-plate, until it is long enough to be attached to the block, which is furnished with a small vice for the purpose of grasping the wire firmly. The workman then presses the lever with his foot, and the block drops down upon a clam fixed to the top of the upright revolving shaft, as before noticed, and is carried round by the machinery, drawing with



WIRE-DRAWING.

it the wire through the plate, and winding it in coils round the block. When the whole of the wire is thus coiled, the block is again lifted off the clam; the wire is removed, and the workman proceeds to draw another piece.

The various blocks are made to revolve at different rates of speed, by varying the size of the mitre or bevel wheels under the bench. The thickest and strongest wires are acted on by those which move slowly, and as it becomes drawn out it is moved at a gradually increasing rate of speed. There are usually about four rows of blocks revolving at different speeds; the swiftest motion reducing the wire to about No. 19 or 20 on the wire gauge. It is then passed to the *card wire drawers*, or *fine wire drawers* (who often form a distinct trade), and is reduced by them to the finest numbers, in some cases as fine as No. 40, which, when formed into wire gauze of the finest texture, will have 120 wires each way in an inch, forming 14,400 wires, and as many spaces, in the square inch.

The effect of forcing a rod of metal through a hole in the draw-plate smaller than itself is not only to extend the length of the rod, but also to condense the fibres, and render the wire so hard, that it is found impossible to continue the drawing without adopting some method of softening the wire. At the works at Birmingham visited by the writer, the plan adopted for this purpose was to anneal the wire in cylindrical kilns, about four feet in diameter, and ten feet in depth, made of iron, and cased on the outside with fire-brick. The wire, after having passed through the draw-plate several times, is thrown in coils into these kilns, first the large coils, and then, for economy of space, the smaller ones, each kiln containing from twenty to thirty hundred weight of wire. The cylinder is then carefully closed to exclude air, and a fire is lighted under the kilns sufficient to bring the wire to a red heat; this being done, the fire is left to go out, and the wire to cool gradually, twenty-four hours being occupied in this heating and cooling. The number of annealings depends on the state of fineness to which the metal is to be reduced, and also in some degree upon the quality of the metal. Wire made from charcoal iron requires less annealing than that made from iron smelted with coal or coke. In the production of very fine wire, the annealing is repeated six or eight times. The effect of this annealing is slightly to oxidise the wire; and if this oxide were not removed, it would by its hardness cut or streak the draw-plate or fix on the wire, giving it a tarnished appearance, or cause it to break when drawn very fine. To remove this oxide, the wire is secured or cleaned by pickling in a solution of sulphuric acid. The card wire drawers draw the wire through the plate from a reel contained in a tub full of starch water or stale beer grounds, the effect of which is to remove the oxide that may adhere to the surface, and give a bright clear colour to the wire.

In the course of wire-drawing the holes in the draw-plate are apt to become enlarged. When the workman finds this to be the case, he reduces the size of the hole by blows with a hard hammer on the flat surface of the plate.

The size of wire is determined by a gauge, which is a steel plate, containing nicks or grooves in the margin, and numbered from 0000, or four sizes below No. 1 up to 30 or 40, beginning in some gauges with the largest and in others with the smallest size. In the former case wire of about three-tenths of an inch in diameter is called No. 1, and the sizes decrease to No. 26, which is under one-fiftieth of an inch. The want of a uniform standard often leads to great inconveniences; as, for example, a wire-worker may order wire from the manufacturer by a number on his own gauge, while the gauge used by the manufacturer may be quite different.

THE MANUFACTURE OF NEEDLES.

Here the needle plies its busy task,
The pattern grows, the well depicted flower,
Wrought patiently into the snowy lawn,
Unfolds its bosom ; buds, and leaves, and sprigs,
And curling tendrils, gracefully disposed,
Follow the nimble finger of the fair ;
A wreath, that cannot fade, of flowers that blow
With most success when all besides decay.
The poet's or historian's page by one
Made vocal for the amusement of the rest ;
The sprightly lyre, whose treasure of sweet sounds
The touch from many a trembling chord shakes out ;
And the clear voice symphonious, yet distinct,
And in the charming strife triumphant still,
Beguile the night, and set a keener edge
On female industry—the threaded steel
Flies swiftly, and unfelt the task proceeds.
COWPER.

THE manufacture of the little instrument, whose task the poet has so well described in the above passage, and which ministers so extensively to the ordinary employment of females, cannot be uninteresting or uninstructive; and it is fortunate that manufacturers are sufficiently liberal to allow the many curious and beautiful processes concerned in the production of these tiny articles to be described. In former times such details were kept with such jealous secresy by those who exercised them, that the term *mystery* (which is still used in apprentices' indentures) had a very significant meaning. Under the dread of competition, it was considered of importance to keep from the public a knowledge of manufacturing details, and in this way much valuable and curious information doubtless became lost for want of a historian. Thus we know nothing that can be relied on respecting the introduction of the needle manufacture in this country, nor of the progressive steps by which the clumsy bodkin was superseded by the light and elegant steel needle. Pliny mentions needles of bronze, specimens of which, both for sewing and for knitting, occur in the Hamilton Collection. Pins and bodkins of bone and ivory have been found in British barrows, and these bodkins resemble the needles used by many rude nations at the present day. Captain Parry notices the dexterity of the Esquimaux women "in that important branch of a housewife's business, sewing, which, even with their own clumsy needles of bone, they perform with extraordinary neatness, using as thread the sinew of the reindeer, or the swallow-pipe of a species of seal, split into different sizes, according to the nature of their work." Their thimbles are of leather, and are worn in sewing on the first finger. "In sewing, the point of the needle is entered and drawn through in a direction towards the body, and not from it, or towards one side, as with our seamstresses. They sew the deer-skins with a 'round seam,' and the water-tight boots and shoes are 'stitched.' The latter is performed in a very adroit and efficacious manner, by putting the needle only half through the substance of one part of the seal-skin, so as to leave no hole for admitting the water."

Fine sewing needles of steel seem to have been invented in Spain, at least if the term "Spanish needles," formerly applied to them, is at all significant of their origin. One of our old chroniclers (Stow) states, that the making of Spanish needles "was first taught in Englande by Elias Crowse, a Germaine, about the eighth yeere of Queene Elizabeth; and in Queene Marie's time there was a negro made fine Spanish needles in Cheapside, but would never teach his art to any." Another writer states, that "needles were first made in England by a native of India (probably the negro mentioned by Stow) in 1545, but the art was lost at his death; it was, however, recovered in 1650 by Christopher Greening, who settled, with his three children, at Long Crendon, in Buckinghamshire."

The present seat of the needle manufacture is principally Redditch, a picturesque village in Worcestershire, about fourteen miles to the south of Birmingham. It is the chief manufacture of the place, most of the inhabitants being more or less concerned in it. Two other articles are manufactured at Redditch; namely,—Fish-hooks, and hooks and eyes; the latter only to a small extent. Needles are also made at the villages of Feckenham, Beoley, Studley, Coughton, Alcester, Astwood Bank, and Crabb's Cross, all of which, including Redditch, are near together. They employ about ten thousand persons in needle making.

The various processes concerned in the production of needles are carried on principally in factories (or *mills*, as they are called), of which there are about a dozen in Redditch,* employing altogether between six and seven thousand persons—men, women, and children. There is nothing remarkable in the appearance of the factories; the rooms are, as usual, well lighted by numerous ranges of windows, and are furnished either with steam or water power for giving motion to the wheels and apparatus concerned in the grinding and polishing of the needles. Most of the processes, however, are performed by hand, and some at the cottages of the operatives. These processes are very numerous, and afford a remarkable instance of the division of labour, and of the value conferred by labour on a raw material of small value, for some of the finest sorts are worth nearly their weight in gold.

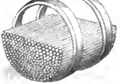
---

* The writer has to express his acknowledgments to Mr. Samuel Thomas, of the British Needle Mills, for the kind and liberal manner in which his extensive and well-conducted factory was thrown open for the purposes of the present treatise.

The needle manufacturer receives his raw material from Sheffield or Birmingham, in the shape of soft clean steel wire, formed into coils of various sizes and weights. The sizes of the wire are known by numbers corresponding to certain slits, also numbered, in a small steel plate, called a *gauge*. The wire known as No. 1 is one twenty-second part of an inch in thickness, and exactly fits the slit No. 1 in the steel gauge; No. 12 is only one hundredth of an inch in diameter; the intermediate numbers being, of course, of intermediate thicknesses. The wire is what is called *hand-drawn*, in contradistinction to *mill-drawn*. In both cases the wire after passing through draw plates is wound upon a drum, only in the latter many drums run together, and if each drum delivers its proper quantity of wire the result is deemed satisfactory. In the former case there is only one wire running at a time, so that when the surface *rips* or *tears* the attendant can feel it and stop the process so as to remove the damaged part. In this way good surfaced wire is produced. The coils of wire as received by the needle-maker are first cut into lengths for making two needles, which is done by inserting the wires between the blades of a pair of shears, fixed to the wall of the cutting-shop, the workman pressing the shears together with his thigh. The number of pieces thus collected will, of course, depend on the size of the needle; and supposing

No. 6's are being made, enough wire is uncoiled to cut up into twenty-five or thirty thousand pieces, each piece about three inches long, or enough to make two needles. These pieces having been cut from a coil are of course more or less bent; they must, therefore, be straightened, or serious errors would damage the subsequent processes. The method of straightening is simple and ingenious. Several thousand wires are collected in a bundle by two tolerably broad and heavy rings drawn over them, and holding them together like a faggot. In this state they are placed on a shelf in the furnace, where they are heated to redness; they are then taken out and placed on an iron plate, still retaining their position within the rings. The workman then takes an instrument, called by a curious contradiction of terms, a *smooth file*, and placing it in the space between the two rings, rubs the wires backwards and forwards, thus making them roll over each other, when, by mutual

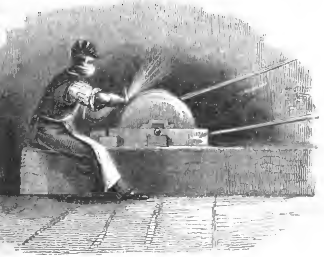
CUTTING THE WIRE INTO LENGTHS.



friction and attrition, they straighten each other. The noise given out by this process of *rubbing*, as it is called, is very similar to that of filing; at first it is rough, but quickly softens down to a subdued note, which informs the workman that the object of his operation is accomplished.

STRAIGHTENING THE WIRE.

The wires being thus straightened, the two ends are pointed by grinding upon small grit stones of ten or twenty inches in diameter, varying with the size of the needle. The stones are made to rotate rapidly, and the workman, seated on a stool or wooden horse, takes a number of wires in his left hand, spreads them out, and keeps them parallel by placing the other hand upon them in a peculiar way, moving it so as to make all the wires rotate backwards and forwards, in order that a perfect cone or point may be formed. Sometimes a piece of stout leather, called a *thumb-piece*, is used, with which the grinder presses the wires against the stone. Every now and then he adjusts the points, by pressing them against a plate, and also dips them into a trough of water, to keep them cool. He can form several thousand points in an hour. On applying the ends to the stone, a brilliant stream of sparks is produced, and the minute particles of steel and grit thus liberated fill the air with a dust which enters the man's lungs at every inspiration, producing what is called *grinders' asthma*. So fatal is this disease, aggravated, as it too often is, by intemperate habits, that the grinder becomes an old man at thirty, and usually dies at thirty-five, or before forty. His only protection against the destructive atmosphere which he breathes is a handkerchief tied over the mouth, and he refuses to make use of the ingenious inventions which have been contrived to render his occupation harmless, under the idea that, if adopted, the effect would be to lower his wages. If, instead of being an illiterate and dissipated class, the grinders were intelligent and sober, they would not prefer a short life, high wages, and little work, to the freedom from


POINTING THE NEEDLES BY DRY GRINDING.

Digitized by Google

pain and suffering which would result from rendering their occupation healthful; and there is no doubt that dexterity and skill such as theirs would always produce a fair remuneration.

If, instead of dry grinding, the wet method could be adopted, much of the danger of this occupation would be removed. If water, however, were made use of, the points of the wires would become speedily rusted. In the year 1821, Mr. Abraham, of Sheffield, invented a mask for covering the mouth and nostrils. It consists of a small frame of wood, covered with two or three layers of crape or muslin, and studded with several small magnets, which attract the particles of steel in their passage to the mouth of the wearer, while the crape filters the air of the particles of grit. As the mask becomes loaded with these particles, all that is necessary to clear it is to take it off once or twice in the course of an hour, and give it a few gentle taps. This simple apparatus was found to be perfectly effective, and although it has been invented for nearly forty years, and needle-grinding is as destructive as ever, the men still continue to reject it, as they do also another piece of apparatus, consisting of a pipe or conduit leading from the grindstone through the wall of the grinding-room into the open air. In this pipe a strong current of air is generated by means of a fan, the effect of which is to draw away the particles of steel and grit from the grindstone as soon as they are formed, and convey them at once into the open air. This apparatus, which is used in the grinderies of Sheffield, has had the happy effect of adding ten years to the average of a grinder's life.*

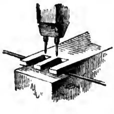
---

* Since the writer's visit to Redditch, pipes with fans, for creating a blast, have been introduced into the principal manufactories, for the purpose of clearing the atmosphere of this pernicious dust, which by the constant current of wind thus excited, is conveyed by means of a funnel into the open air. The grinders already begin to see the benefit they derive from such an improvement.

The needle as it leaves the grinder is a straight piece of soft dingy wire, pointed at each extremity. The points being examined to see that they are properly formed, then comes the important business of forming the eyes in the centre of each wire, which is to make two needles. In the success of this process, the time and comfort of the seamstress are greatly concerned. The manufacturer is enabled to attach to his label the important words "warranted not to cut the thread," by a series of nice and delicate processes which are far more effective than gold and silver eyes, which were once so fashionable.

The reader need scarcely be informed that the eye of a needle consists of a perforation at the thick end of it, together with a groove or *gutter* on opposite sides, for the purpose of guiding the thread, in "threading a needle." If it were attempted to form these by one operation of stamping, the metal would probably be torn and rent asunder, and so damaged by the blow as to spoil the wire. The object is therefore attained by two or three separate cautious steps. First, the gutter is formed, together with an indentation at the spot intended for the hole, by means of a stamping machine, which consists of a bed of iron containing the under half of a die or stamp, supported on a heavy block of stone. Above this is a hammer of about twelve pounds weight, containing the other half of the die. This hammer can be raised by a lever commanded by the foot. The workman holding several wires, drops one at a time upon the iron bed, pushing it up against a piece of metal adjusted so as to determine the length of the needle; then raising the hammer with his foot, lets it fall with a smart blow. The two raised faces of the die produce two opposite indentations on the wire, bulging out a portion of its substance. Although the stamper has to adjust and stamp every wire separately, he can operate on two thousand wires, equivalent to four thousand needles, in the course of an hour.

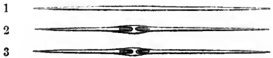
The eyes are next pierced through by small hand presses, which are worked by boys; each boy takes a number of wires, spreads them out like a fan, places them in a notch formed in a small iron slab, bringing the middle of the wire to the middle of the press. The upper arm of the press contains two steel points or cutters of the exact size of the eye, which fall over corresponding holes in the die. The boy, holding his head close to his work, brings this arm down and cuts or punches out the eye. As each wire is pierced, the boy shifts the fan of wires so as to bring a fresh wire under the punch. This is called *eyeing the needles*, and for some *sorts* is performed in a different manner. For instance:—as soon as the wires are pointed at the two ends, they are cut in the middle by means of the upright shears already noticed, and then laid parallel to each other in small wooden boxes, and transferred to the head-flattener. This workman, seated at a table, with a cubical block of steel before him, takes up by the points twenty or five-and-twenty needles between the finger and thumb of his left hand, and spreads them out like a fan; he lays the ends of the wires upon the steel block, and with a small hammer strikes them in succession, so as to flatten the end of one wire at every blow. The effect of this blow is to harden the ends of the wires; they are, therefore, annealed by being heated and slowly cooled, and then given to the *piercer*. This is generally a child, who, placing the ends on a block of steel, applies the point of a small punch to each, and pierces the eye by the smart tap of a hammer; the ends are then turned over and pierced on the opposite side. Another child trims



the eyes by placing each needle upon a lump of lead, and driving a punch through its eye; then placing it sideways upon a flat piece of steel with the punch sticking in it, taps it on each side with the hammer, thereby making the eye assume the shape of the punch. All this is done with astonishing rapidity.

By this method of piercing, the groove is formed last. The needle is fixed in a pair of pincers held in the hand, and the head rested in an angular groove cut in a piece of hard steel; then with a single stroke of a small file applied to two opposite sides of the head, the gutter is formed. The head is next rounded and smoothed with a small file.

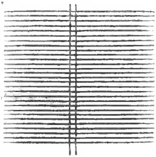
The method of eyeing the needles by punching the eyes and gutters in the middle of the double wire, is the most expeditious and economical, and, where practicable, is generally adopted. By this method the wires in their successive stages present the following appearance:—1. The straight wire pointed at both ends. 2. The same wire flattened out in the centre, with the impression of the eye and gutter. 3. The same wire with the eye perforated.*



The bur produced on each side of the eye in the process of stamping, has now to be filed off, but as this would be a slow process if performed on the wires separately, a number of them are collected together by a very ingenious process; they are *spitted* on fine wires, as shown in the following figure, a wire being run through each line of eyes. This work is performed by children with great rapidity. The bur is then removed with a flat file, after which the separation takes place by bending the needles backwards and forwards between the two spits, thus producing two separate rows of needles, each row spitted on a wire. The points of each row are then grasped in a kind of hand vice, and the heads filed to

---

* In the second and third figures the artist has not placed the eyes in the centre of the wires: this is a mistake.



the proper shape. The needles are now of the proper length, although still in the rough state, but they are so far advanced as to have an eye, a gutter, and a point.

In the process of stamping and spitting and separating the needles, some of them become bent; they now go to the *soft straightener;* that is, being still in the soft state they are made straight by rolling on a flat steel plate, with a smooth steel file, turned up at each end so as to present a convex surface, with which the work is performed. A number of needles being put on the plate parallel to each other, the straightener, generally a woman, taking them one by one, gives them a few turns backwards and forwards, by which rolling between hard unyielding surfaces they become straight. One woman can straighten a thousand needles in an hour.

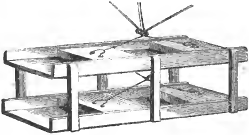
This ends what are called the *soft processes*. The needles are still black, dingy, and soft, and therefore quite unfit to ply their busy task, guided by nimble fingers. They have now to be *hardened,* for which purpose they are spread, by means of two little trowels, in a thickish layer on narrow plates of iron, and placed on a shelf in the furnace. Here they are brought to a low red or *worm-red* heat, and are then taken out and suddenly cooled by being plunged into cold water or oil. The effect of this operation is to make them very hard and brittle, but they are too much so for use, and require to be made less so by the process of *tempering:* that is, when taken out of the water and dried, they are again heated, but not by any means to so high a temperature as in the former case, and are allowed to cool gradually. For this purpose they are placed on an iron plate heated by a fire beneath, and are kept in constant motion for about five minutes with small iron shovels: the moment a film of blue oxide forms upon them the needles are considered to be of the proper temper, and are instantly removed from the plate.

In hardening the needles by plunging them into cold water, they all become more or less bent: they are therefore submitted to *hard* or *hammer straightening*, which is generally done at the homes of the workpeople. The needles are rolled by the finger on a smooth steel slab, and the touch, assisted by sight, instantly detects such as do not roll truly; these are picked out, placed on a small anvil, and tapped with a small hammer, whereby they are effectually straightened.

Next comes the important process of *scouring* or *cleaning*, commencing what are called the *bright processes.* As the wires were made straight in the first instance by mutual attrition, so by a similar operation they are made bright. For this purpose they are made up in bundles of forty or fifty thousand by the following contrivance. A number of strings are put across a wooden tray open at the two ends; upon these strings is placed a piece of stout canvas, and within the

Google

canvas the needles are arranged in heaps in the direction of their length, but without any distinction as to heads and points. A small quantity of emery, oil, and soft soap being sprinkled over them, they are rolled up into a bundle, and tied up temporarily. The bundle can then be lifted up without danger of the needles falling out. The man then takes a piece of strong twine and winds it laboriously round the bundle, in a tolerably close coil, removing the string as he advances with the twine, so as to form a compact bundle two or three feet long, and about three or four inches thick. A number of such rolls being prepared, they are put under the *scouring machines,* which consist of an arrangement of troughs containing weighted slabs or rubbers, under which the bundles of needles are moved backwards and forwards in the same way as the rollers of a common mangle. The rubbers make twenty or thirty movements in a minute, pressing heavily on the rolls, and causing the needles to rub over and over each other, so that by constant friction during fifty or sixty hours, aided by oil, emery, soft soap, and polishing putty, a bright surface is obtained. The rubbing is not continued for more than eight hours at a time; for the constant friction wears out the canvas in which they are folded, and the roll requires re-making. The needles are therefore unpacked,


SCOURING MACHINE.

washed in soap and water, again tied up, with the addition of polishing putty and oil, and rubbed for another eight hours. This is repeated every day for seven or eight days for the best needles. This is rough usage for so slender and brittle an instrument as a needle, and the breakage is often considerable. Of course, the more rubbing the greater is the amount of breakage, but the needles improve considerably in appearance and quality by this scouring, which would seem to impart something more than polish, and to exert a sort of annealing effect on the metal.

The needles are now bright and clean in appearance, but by no means finished. They are sent from the scouring room to the *bright-shop*, where by a peculiar shaking motion in long tin trays, they are all brought parallel. They are then made up into long rows or heaps, and are passed to a little girl called the *header*, whose business it is to turn all the heads one way. To do this for forty or fifty thousand needles would seem a difficult and endless task, and yet it is accomplished with a degree of rapidity and exactness which creates astonishment, and by a process so simple that it excites a smile. The child has a piece of rag or soft leather wrapped round the fore finger of the right hand, which she presses against the pile of needles, and of course all the points which happen to lie in that way run into the rag, and retain sufficient hold to admit of their being lifted up and dragged out of the pile; and thus, being supported at the heads by a finger of the other hand, they are ranged in a fresh pile, so that when the work is complete, the lot of needles is arranged into two piles, with the points opposed to each other.

At this stage of the proceedings the needles are again examined, and all broken and defective ones removed.

Next comes the delicate and important operation of *drilling* the eyes, or in other words, removing from each eye the sharp edges, which in inferior needles cut the thread, and waste the time of the seamstress. To effect this it is necessary further to temper the needle, at and about the eye, so that it may be soft enough to be cut by a drill. This is done by placing the needles on a steel slab, with their heads projecting over the edge; a red-hot plate is then cautiously brought near to them, and the moment they begin to feel the heat they change colour, passing through various shades of yellow and purple until they assume a dark blue colour, which shows the proper temper for working.

The drills are small three-sided instruments of steel, three or four inches long, and are prepared with the nicest care. The drilling is performed by young women, seated at a bench opposite a window, with the tiny drills revolving with great speed before them. The constrained attitude of the drillers is

DRILLING AND POLISHING.

remarkable, and almost painful to look at; the eye is rigidly fixed and held at some distance, as if for long sight, while every muscle of the body is apparently rigid to prevent tremor or unsteadiness of hand. The driller, taking up a few needles by the points in the left hand, spreads them out like a fan, and brings them opposite the point of the drill, which is managed with the right hand; by a peculiar motion of the thumb and fingers of the left hand, the eyes are successively brought under the action of the drill. First, each eye is counter-sunk, that is, it is bevelled off with the drill so as to join the gutter by a rounded instead of a sharp edge. The drill is then passed round the rest of the edge of the eye, taking off its sharp edge, and making it like the inner surface of the bow of a pair of scissors. Both sides of the eye are operated on in this manner.

This drilling is a modern invention, and is a real improvement, as the drilled needles are little if at all liable to cut the thread, and they rarely break in the eye, because they must be made of the best material, and be blued or softened to allow the drill to cut; hence they are not so brittle as the common needles, which are not drilled.

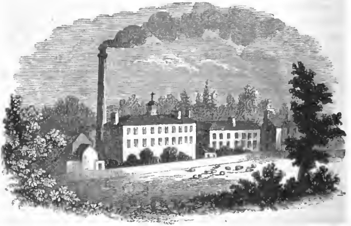
Gold-eyed needles are produced by dipping the head of the needle in ether containing gold in solution, which immediately attaches itself to the steel. This is a refinement which serves only to increase the cost of the article without adding to its utility.

After the needles are drilled, the points are finished on a small hone-stone, mounted in a lathe, and revolving with great rapidity. The needles are then passed to the polisher, who polishes them on wheels of wood covered with buff leather, slightly smeared with a polishing paste.

The needles are now ready for papering. They are counted into quarters of hundreds, which are folded up in blue papers and labelled. These packets are then made up into bundles of twenty papers each, and these again into square *packets*, containing twenty, forty, or sixty thousand needles, which if intended for exportation, are packed in soldered tin cases.

The processes as above described apply only to the fine sorts of needles; some of the finishing processes being omitted for the coarser sorts, such as *packing, sail, upholsterers', stay, mattress, bookbinders', surgeons', harness* and *collar* needles, to which may be added *knitting, netting,* and *meshes*, and *tambour* and *crochet* needles. A hundred million fine needles are manufactured in the course of a year at the mill visited by the writer; and in Redditch and the neighbourhood, seventy millions per week.

Such is the history of the needle manufacture; and it has been well remarked, that "when we survey a manufacture of this kind, we cannot fail to observe, that the diversity of operations which the needles undergo, bears the impress of great mechanical refinement. In the arts, to divide labour, is to abridge it; to multiply operations, is to simplify them; and to attach an operative exclusively to one process, is to render him much more economical and productive."



THE BRITISH NEEDLE-MILLS, REDDITCH.

THE

MANUFACTURE OF FILES.*

WITH the exception of the hammer, there is probably no tool more extensively useful than the file. It is found in the hands of workmen in almost every department of the useful arts, although its chief application is in working metals. The origin of this invaluable instrument is quite unknown. It is mentioned in sacred history (1 Samuel xiii. 20, 21), that "all the Israelites went down to the Philistines, to sharpen every man his share, and his coulter, and his axe, and his mattock. Yet they had a *file* for the mattocks, and for the coulters, and for the forks, and for the axes, and to sharpen the goads." It has been supposed from this passage that the revolving grindstone was then unknown. The file is also mentioned by Homer, who represents Vulcan working with a hammer and file.

It is scarcely necessary to state, that a file is a piece of steel with a number of teeth upon its surface, capable of abrading or wearing down substances softer than itself. A tool in such common use is, of course, varied in shape and size and fineness to an almost infinite extent. Some files are expressly adapted to particular purposes; others are in general use, and these may be *round* like a cylinder, *tapering* like a rat's tail, *half round,* that is, flat on one side and rounded on the other; or they may be *triangular* or *three-square, square* or *four-square:* a file may also be large or small, blunt or pointed, straight or curved. The teeth may be cut in a variety of ways, such as coarse or fine, the former having only ten or twenty to the inch, and the latter from a hundred to a hundred and fifty. When these teeth are cut with a straight sharp-edged chisel extending in a single cut across the surface, they form what are called *floats;* but when these cuts are crossed by a second series at an angle, they form what are properly called *files;* and when formed by a triangular pointed chisel which drives up little pointed portions over the surface, they are called *rasps.* When the teeth form a single series of sharp edges across the file, the file is said to be *single cut;* but when these teeth are crossed by a second series of similar teeth, the file becomes a *double* or *cross cut.* The first is used for brass and copper and the softer metals generally, and the latter for the harder surfaces of iron and steel. The surface of a double cut file presents a series of keen teeth, which penetrate and wear down hard metallic surfaces, but soon become clogged and useless, when used on the softer metals, brass and copper. A single cut file, on the contrary, would slip over iron and steel without producing any effect, while it would effectually abrade a softer metal.

---

* The writer has to express his acknowledgments to Messrs. Beardshaw, Stevenson and Co., of Sheffield, for the liberal manner in which their factories were thrown open to himself and the artist.

The various degrees of fineness in files have their distinguishing names. Extremely rough files are called *rough;* next to these are the *bastard cut;* then *second cut;* fourthly *smooth,* and fifth, the finest of all, are called *dead smooth:* the term smooth indicating that the teeth are sufficiently fine and close to produce upon metal a nearly smooth surface fit for polishing. The very heavy square files used for smiths' work, which are often coarser than the rough, are called *rubbers.* When it is considered that all the classes and varieties of files are made of various lengths, from two or three up to twenty inches long; and taking into account the various rasps and rubbers, and the heavy files which form a medium between rasps and rubbers; the small delicate steel files of the watchmaker and others,—it will readily be supposed that the file manufacture embraces many thousand distinctions, and is of great importance as a branch of national industry.

Sheffield is the head quarters of the file manufacture, probably on account of the facilities for procuring steel of the proper quality; and this quality must be good; for if too soft or unequal in texture, the file itself would soon be worn down instead of the metal to which it is applied: if, on the contrary, it be too hard, the teeth are brittle and chip off at every stroke. Smiths' rubbers are forged square from the bars of blistered steel as they leave the converting furnace; smaller files are forged from rolled bars or tilted rods of various shapes and sizes, according to the kind of file required; files of the very best quality being made from cast steel. The iron bearing the C C N D mark makes excellent steel for files; but the finest files which are used by watch and clock makers are made from the hoop L or Dannemora iron. The steel for files is more highly converted than for any other purpose.

The finer varieties of files, such as are used by watch and clock makers, mathematical instrument makers and others, are distinguished as *Lancashire-made;* Warrington, in Lancashire, being the principal seat of the manufacture. Lancashire files, and Sheffield files, are distinguished according to the fineness of the teeth, in the following manner:—

Lancashire Files.	*Sheffield Files.*
1. Rough	1. Rough
2.* Middle-cut	2. Bastard
3. Bastard	3. Second-cut
4.* Second-cut	4. Smooth
5. Smooth	5.* Dead-smooth.
6. Superfine.	

The sizes marked * are not usually made, so that we may consider that there are four degrees in each scale, the Lancashire being somewhat finer than the

Sheffield made. A superfine Lancashire-cut file four inches in length may have as many as 216 cuts in the inch; the smooth, 112; the bastard, 76, and the rough, 56.

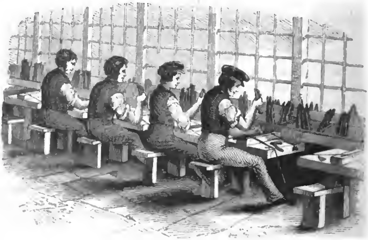
Files used for filing out rectangular corners and for other purposes, have one or more of their edges left uncut, or *safe* as it is called, so that when rubbing against the work it may guide the cut part of the file without acting on the part which they rub.

In the forge, where the files are first formed, coke is used as fuel: the anvil is firmly wedged into a large block of millstone grit resting on the earthen floor. In forging files two men are employed—the *maker* and the *striker;* the former is the superior workman and directs the operation; the latter is his assistant, and he manages the fire, heats the steel, and performs the most laborious part of the work. He is furnished with a large double-handed hammer, with a broad face at either end; the hammer wielded by the maker is smaller and single-handed, somewhat conical in shape, the wider end forming the face. Three-square and half-round files are forged in grooved bosses or dies fixed in the anvil. The rod of steel being made sufficiently hot, the end is hammered till it fills the die; the maker holds the bar and strikes with the small hammer; the striker standing before the anvil, deals powerful blows on the heated metal, the flat faces of the hammers covering a considerable portion of the surface of the file at each stroke, expanding and levelling it at one operation. This is very fatiguing work, especially as the hot rod yields no rebound to the hammer. When the file is forged to the proper length, the tang is also drawn out by cutting into the file a little on both sides with a chisel, so as to form in many cases sharp and square shoulders, and then drawing out the part so cut to form the tang. The maker's mark or monogram is next impressed. Round files are formed by a swage, similar to that used by the blacksmith, but slightly conical. Flat and square files are formed entirely by hammering. The maker accustoms himself as much as possible to the forging of one description of file, so that by attention to one article he attains perfection in its manufacture.

The forged blanks are next annealed or *lighted*, in order to make the metal soft enough for cutting the teeth. For this purpose the blanks are loosely piled within a brick oven; a fire is kindled below and around them, and is regulated by means of dampers during four-and-twenty hours. One or two of the blanks are then examined, and if sufficiently soft, the pile is covered with ashes and left to cool slowly. The very best files are annealed by being shut up in an iron box, with sand to exclude the air.

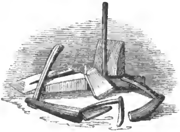
The surface of the blank is not sufficiently uniform and smooth for the purpose of cutting. It is made so by *stripping* or *grinding*. Stripping consists in smoothing the surface of the blank with a hard file, first across and then lengthways; but the more common method of preparing the blanks is by grinding upon a large revolving stone of a compact texture and about eleven inches broad. When in use the surface is kept immersed in water, the grinder leaning over the stone, the motion of which is from him. The operation is a dirty one, and is usually performed in a shed or outhouse, or in one of the old Sheffield mills, where the grinder pays a certain sum for the use of the moving power.

After the grinding the blanks are ready for the curious operation of cutting or raising the teeth. It is scarcely possible to examine attentively the teeth of a fine file, without being struck with their beauty and regularity, but how greatly is our admiration increased when we find that these teeth are cut singly with a hammer and chisel, the workman having no other guide than delicacy of touch and precision of eye, depending, however, rather upon the former sense than the latter. The cutting room is a long narrow apartment, with a range of windows in front, opposite which are placed a number of low



CUTTING FILES.

stone benches for the anvils, and seats for the workmen. The hammers used weigh from one to six pounds, acording to the size of the file: they are curiously formed, the handle being so placed as to allow the mass of metal to be pulled towards the workman while making the blow. The chisels are formed of good tough steel, and also vary with the size of the file; they are somewhat broader than the file to be cut, and are sharpened to the proper angle; they are only just long enough to be held between the fingers and thumb somewhat as a pen is held, only in the left hand, the hollow of the hand being turned to the workman. But the peculiar method of handling the chisel depends in great measure on the kind of tooth to be cut. The file is held to its place on the anvil by means of a leather strap passing over each end of the file and then under the feet of the workman, in the manner of stirrups. At every blow of the hammer the chisel is made to cut a tooth; and the blows follow each other in rapid succession, the



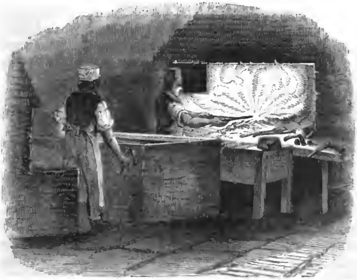
FILE-CUTTER'S TOOLS.

workman after every blow advancing the chisel forward by so slight a movement as to be scarcely perceptible. In this he is guided by the effect produced on the steel, which is well described by Mr. Holtzapffel: "The blow of the hammer upon the chisel causes the latter to indent and slightly to drive forward the steel, thereby throwing up a trifling ridge or *bur;* the chisel is immediately replaced on the blank and slid from the operator, until it encounters the ridge previously thrown up, which arrests the chisel or prevents it from slipping further back, and thereby determines the succeeding position of the chisel. The heavier the blow, the greater the ridge, and the greater the distance from the preceding cut at which the chisel is arrested. The chisel having been placed in its second position is again struck with the hammer, which is made to give the blows as nearly as possible of uniform strength: and the process is repeated with considerable rapidity and regularity, sixty to eighty cuts being made in one minute, until the entire length of the file has been cut with inclined, parallel, and equidistant ridges, which are collectively denominated the *first course.*" The chisel forms a number of angular grooves parallel to each other, the tooth being formed by the metal left between every two grooves. The skilful workman adjusts the weight of his blow to the kind of metal he is operating upon; and even in the same file, if one part be softer than another, he adapts the weight of his blow so that the teeth may be of the same size in every part. As the work proceeds he gradually shifts the file forward by loosening his tread upon the straps. When one surface is covered with single cuts, he proceeds, in double cut files, to add a second row of teeth, making them cross the first at a certain angle, for which purpose the chisel requires to be held in a particular manner. When one side is covered, he proceeds in like manner to fill a second side; but as the teeth just finished would be injured by placing them on the naked anvil while hammering, they are protected by interposing a flat piece of an alloy of lead and tin, which completely preserves the side already formed. Similar pieces of alloy with angular and rounded grooves are used in cutting triangular and half-round files. Rasps, as already noticed, are cut with a triangular punch instead of a chisel, every new tooth being placed opposite a vacant space in the adjoining row of teeth. The curved surfaces of files show in a remarkable way the skill of the file-cutter: in them the teeth are formed with straight-edged chisels, many rows of short cuts being made from the top to the bottom of the file, and these cuts uniting together at their extremities thus form a complete series of lines, passing completely round the cylinder or half cylinder as the case may be. In fine round files, as many as from ten to twenty rows of cuts are required to cover the surface with teeth; and when it is considered that there may be upwards of a hundred teeth within the space of an inch, some idea may be formed of the many thousand blows required to raise the teeth on a fine file. In double cut files, when one row of teeth is completed, a fine file is run slightly over them, to moderate the roughness before commencing the second row.

The files are still soft, and are for most purposes perfectly useless as files until hardened:* which is done by heating them to a full red, and suddenly quenching them in cold water. This however is a delicate operation, requiring several precautions, for if the steel be exposed to the air at a red heat even for a short time, oxygen combines with it rapidly, destroying the sharpness of the teeth by covering them with oxide. The surface of the file is therefore protected from the air by dipping it into a solution of common salt stiffened with ale grounds or common flour. When the file is heated to redness this composition forms a kind of varnish, which protects the metal from the air. The annexed engraving shows the arrangement of the forge fire for heating the files, and the trough of cold water into which they are plunged. The workman has also a bench and a few tools, for correcting any bends or twists in the files when softened by heat. For this purpose they are struck with a small leaden hammer upon an anvil of the same material; and also inserted between a couple of iron bars fixed parallel and a little way

---

* Some descriptions of files and rasps, such as are used upon wood, ivory, and other soft substances, are left in their soft state after being cut; such files admit of being sharpened up with a hard file. The files used by sculptors and die sinkers are curved into various forms, and are sometimes made of iron and *case hardened;* that is, the surface of the file is converted into steel by heating it in contact with certain animal substances yielding carbon; while the interior of the file remains iron as before.



HARDENING FILES.

apart, and bent in an opposite direction to the bend which it is intended to correct. When the workman is satisfied with their shape, he brings one up to a uniform cherry red heat, holding it by the tang with a pair of tongs, and turning it over in the fire. The method of plunging it in the water is said to be important, to prevent warping. All files, except the half round, are immersed slowly in a vertical direction: the half round file is quenched by keeping it perpendicular to the surface of the water, moving it through the water in the direction of the round side: but as the convex side contracts much more than the flat surface, there is a general tendency in these files to curl back; this is corrected by bending the file in the opposite direction while hot, and then plunging it horizontally into the water. It is, however, very difficult to avoid some degree of set or curvature in quenching the files. The workman therefore watches each file narrowly, and after plunging it once into the water, if any bending is observed, he is able to correct it before it is quite cold by inserting it between the bars above mentioned, pressing upon it with considerable force and lading the water upon it with his hand: by this method considerable curves may be corrected. The tang is afterwards tempered by immersing it into molten lead, which renders the file much less liable to snap off at the tang, to which it is otherwise liable.

After the hardening, the files are well scoured with scrubbing-brushes dipped into water and sand or coke-dust; they are next put in lime water and left for some hours, in order completely to get rid of the salt, which if allowed to remain would soon rust and destroy the files. After being thoroughly dried at the fire, they are rubbed over with olive oil containing a little turpentine, and they are then finished. Before packing them up for sale, the master or his foreman tests every file by striking it against a piece of steel, which he also rubs against the teeth, and he judges of the quality and hardness of the metal as well as the regularity of the workmanship, by the vibratory sensations communicated to his hand. Imperfect files, called *wasters*, are sorted out and sold by the pound weight; the perfect files are wrapped up separately in papers and made up into dozens.

Attempts have been made at various times to produce file-cutting machines. From a variety of causes which need not be entered upon here, these machines have failed to accomplish their object satisfactorily, either as respects perfection of teeth or cheapness of production. When it is stated that a lad not very experienced in the business will produce with his hammer and chisel nearly a hundred teeth in a minute, the introduction of a machine for doing the same work would seem scarcely desirable. It happens, however, in this, as in many other cases, that obstinate combinations of the workmen against their employers stimulate the inventive faculties of the latter, or lead them to patronise invention in others, so that in course of time machines which for centuries may have failed to supersede the skilful workman may be made very much to exceed him in rapidity and excellence of production. There are many such examples as these in the history of the useful arts, which ought to act as cautions to the skilled workman. Attempts have been made at different times within the last two or three centuries to cut files by machinery, and should these attempts be renewed in our own day there can be but little doubt of complete success. The file-cutters of Sheffield may combine to break such machines, and blow up with gunpowder the mills in which they are introduced, as has been already done on several occasions, but with the usual shallow reasoning of discontented rioters they seem to suppose that Sheffield is the only spot in the kingdom where files can be extensively and efficiently produced. It may be found necessary at some not very distant day, to establish file-cutting

Digitized by Google

machines in a remote village (similar to Redditch, the principal seat of the needle manufacture), and to instruct the inhabitants in the few simple processes required in addition to the important operations of forging and cutting.

MANUFACTURE OF SAWS.

The ancient Greeks honoured the inventor of the saw with a place in their mythology; but, unfortunately for the fame of this individual, his claim is disputed by two others. Beckmann has collected the opinions of ancient writers on the subject of this invention, which, according to some authorities, was made by Talus, son of the sister of Dædalus, whose mother placed him under the tuition of her brother, for instruction in his art. Having on one occasion found the jaw-bone of a snake, he used it in cutting a small piece of wood, and was thus induced to form a similar instrument of iron. This invention of the saw so greatly excited the envy of his master that he put his apprentice to death. While engaged in burying the body, some one in passing inquired what he was burying in the earth; and he replied, "A serpent." This suspicious answer discovered the murder; and thus, adds the historian (Diodorus), a snake was the cause of the invention, of the murder, and of its being found out. Other writers refer the invention to one Perdix (also a son of Dædalus's sister), who did not employ the jaw-bone of a snake, but the back-bone of a fish. The small bony processes which project from the spine of a fish have some resemblance to the saw, but it would not be possible to saw wood with them. "The jaw-bone of a fish furnished with teeth would be more proper; but the words *spina in medio pisce* prevent us from adopting that alteration. I should rather be inclined to explain this difficulty by the bone which projects from the snout of the saw-fish, called by the Romans *serra*, and by the Greeks πρίστης. That bone, indeed, might not be altogether unfit for such a use: the teeth are strongly united to the broad bone in the middle, and are capable of resisting a great force; but they are placed at rather too great a distance. The old inhabitants of Madeira, however, we are told, really used this bone instead of a saw." Pliny claims the invention of the saw for Dædalus himself. It is, however, extremely probable that these mythic personages were invested with inventive genius by the ancient poets and historians, who, "finding in the structure of various animals parts somewhat resembling the saw in use among them, fancifully pursued the analogy, and by a natural and easy fiction, transposing cause and effect, they referred to the origin what properly belonged to the illustration of an idea."

The saws of the ancient carpenters were similar in form to those now in use, as is proved by a painting found in Herculaneum, in which two genii are represented at the end of a bench consisting of a long table resting at each end upon a four-footed stool. The saw resembles our frame-saw: it has a square frame with a blade in the middle, the teeth standing perpendicular to the plane of the frame. The arms in which the blade is fastened have the same form as that given to them at present. The piece of wood which is to be sawn is secured by cramps, and extends beyond the end of the bench, and one of the workmen appears standing and the other sitting on the ground. Montfaucon has given drawings of two ancient saws taken from an older writer. Palladius describes saws not placed in a frame, but fastened to a handle; and Cicero, in his oration for Cluentius, speaks of an ingenious saw with which a thief sawed out the bottom of a chest.

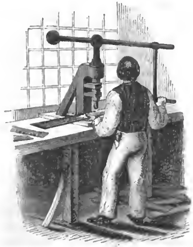
Among the treasures of the British Museum is an ancient Egyptian saw, which was discovered with several other carpenter's tools in a private tomb at Thebes. The blade, which appears to be of brass, is ten inches and a half long, and an inch and a quarter broad at the widest part. The teeth are irregular, and appear to have been formed by striking a blunt-edged instrument against the edge of the plate; the bur or rough shoulder thus produced not being removed. In ancient Egyptian paintings workmen are represented using the saw, the piece of wood which is being cut being held between two upright posts, or bound with ropes to a single post.

In our own day, Sheffield is the great emporium of the saw trade, and supplies not only this country but a large portion of the civilized world with saws. Their forms are almost as various as the uses to which they are applied, the carpenter alone requiring no less than ten different saws, which are thus enumerated by Hebert:—" A *cross-cut* saw, for dividing a tree or log transversely, by means of two workmen, one on each side, who alternately pull the saw towards them, the teeth being made to cut equally in each direction; a *pit-saw* for sawing the logs up into planks or scantlings, the operation being performed in a pit by a vertical motion of the saw, and usually by a class of workmen called *sawyers;* a large *frame-saw*, which is a saw-plate five, six, or seven feet long, stretched in a frame, and used to cut timber longitudinally with greater nicety than the pit-saw; a *ripping-saw*, which is a hand-saw with a blade twenty-eight or thirty inches long, and having large teeth for ripping, or cutting out stuff coarsely and quickly; a *hand-saw* (peculiarly so denominated), usually provided with a twenty-six inch blade, and angular teeth, five to the inch;—a *panel-saw* is the same as the hand-saw, but with finer teeth (seven or eight to the inch), for cutting stuff very clean, and for the more delicate or exact species of work. Saws with very fine teeth, and very thin blades, stiffened with stout pieces of iron or brass, riveted to the back edge, are also used, of several kinds, which are distinguished by the several terms *dovetail, sash, carcase,* and *tenon,* indicative of their uses, and also of their sizes, which vary from six to twenty inches in length; several very narrow saws, indifferently called *lock, compass, key-hole,* and *turning* saws, for cutting out small pieces and rounding work: small *frame-saws,* six or eight inches long, are sometimes required by the carpenter for cutting both wood and iron, the teeth of the latter being smaller and more obtuse than the former." There are many saws used by other mechanics which it would be tedious to enumerate.

A good saw ought to be of uniform thickness in the blade, and of perfect elasticity, so that when bent into the form of a bow, it ought to spring back again into a straight line when the pressure is removed. This quality can of course only be ensured by using a superior metal in the manufacture. The commonest kind of saws are made of iron plates, which are hammer-hardened or planished upon an anvil, to give them some degree of stiffness and elasticity. As their cost is but trifling, "they are purchased in great quantities," says Hebert, "by those who consider any saw to be better than no saw at all." The material most commonly used in the manufacture of saws is cast steel; the latter being preferred for saws as well as for most other tools on account of the uniformity of its structure. The steel is cast in the form of a flat ingot about an inch and a half thick, which is transferred to the rolling mill and rolled out into a large sheet by repeatedly heating and rolling, until it is extended to the proper dimensions. If intended for a mill or pit saw, the whole piece may be required, and it is therefore clipped with shears to the proper shape; but if for smaller saws, it is cut up into suitable pieces. The shears employed for this purpose are very stout, and are arranged with due regard to strength and stability, the upper blade being raised and depressed with a very long lever, as shown in the engraving. The edges of the pieces are next ground perfectly true by holding them against large grindstones.

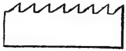
CUTTING OUT THE SAWS.

Then comes the important operation of cutting the teeth, which is done, as in the case of files, by punching or stamping out each tooth separately, and with almost as much celerity. Standing before a fly-press, with the blank held horizontally in the left hand, and the lever of the press in the right, the workman brings down a steel die cutter, which works vertically in a steel die, and cuts out a notch in the left-hand corner; then by a slight onward motion he shifts this notch into an upright piece of steel, which fits it exactly, and cuts out another notch, which in its turn is moved into the steel guide, and a third notch is cut out, the metal between every two notches forming a single tooth, the guide serving to keep all the teeth equidistant.

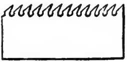


CUTTING THE TEETH.

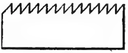
This is done with such rapidity that all the teeth in a saw are cut in the course of a few minutes. In cutting the teeth of long saws which are too heavy and pliable to be held in the hand, the ends are made to rest on two supports hung from the ceiling with cords.



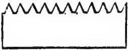
1



2



3



4

The teeth vary in form and size according to the purposes for which the saw is intended. In an ordi-

Digitized by Google

nary mill-saw (1) the teeth are right-angled triangles; in a pit-saw (2) they consist of a succession of demi-lunettes, being the keenest form for cutting; while in the carpenter's hand-saw (3), the cross-cutting saw (4), and most other common saws, the teeth resemble those of the mill-saw, but the spaces at the bottom of the toothing are omitted.

After the cutting, the saw is put into a vice, the wiry edges left by the punch are filed down, and the teeth finished. When a number of workmen are engaged in these operations in one room, the noise is terrific. The reader may probably have had experience of the unpleasant noise produced by *setting* a single saw; but with twenty men in one room moving their files at the same time with wonderful rapidity between the teeth of as many saws, the noise is more easily conceived than described.

The operations of hardening and tempering, which confer their principal value upon most steel goods, succeed next, and require to be conducted with peculiar care. The saws are placed in a reverberatory furnace, and when brought to the required heat, which is known by their being of a cherry-red colour, they are taken out and suddenly cooled by being plunged edgeways into a bath of cold oil, in which certain ingredients have been melted, such as rosin, tallow, suet, pitch, according to the judgment or fancy of the manufacturer, for there does not appear to be much chemical knowledge concerned in the process. Experience has shown, however, that when such large surfaces of steel are suddenly quenched in water, the metal is apt to crack. When removed from the oil bath the saws are very hard and brittle. Large saws are tempered, by stretching them in an iron frame moving on wheels and returning them to the furnace, where they are moved backwards and forwards over the fire till the unctuous matter adhering to the surface of the saw begins to ignite or "blaze off," as the workmen call it, which reduces the metal to the proper temper. During this "blazing off," the saw is removed from the furnace and allowed to cool, and it is occasionally stretched tighter in the frame, so as to remove all tendency to warping. *Back-saws,* or those which are afterwards furnished with a brass or iron back to keep them straight, are made in lengths of several feet, and afterwards cut up into three or four saws. These lengths are hardened and tempered in the same manner as large saws; but saws of middling size are often tempered by holding them one at a time with a pair of tongs, and moving them to and fro over a clear fire until the unctuous matter begins to blaze off. The warping is removed by hammering them on an anvil strewed with sand to prevent them from slipping about.

The next operation, called *planishing* or *smithing,* is an exceedingly noisy operation, but one requiring skill and judgment. The saw being rested on a small anvil of polished steel, is hammered over every part of the surface for the purpose of making it of equal density and elasticity throughout. By giving a kind of vibrating motion to the saw as he hammers, the workman is able to detect weak parts and to strengthen them by hammering up the metal around them. By this means various inequalities which would entirely escape an inexperienced eye are corrected.

The internal texture of the saw being thus equalized, its outer surface is next operated on at the *wheel* or grindstone, to produce that bright and new appearance which is always a recommendation, if not a positive improvement, to steel goods. Grinding is always an unpleasant operation to witness, either on account of the deadly nature of the employment, or the appearance at least of immediate danger, which is very striking. The stones are of large size, being from five to seven feet in diameter, and ten or twelve inches across the face; and the saw when applied to the stone is placed against a board upon which the grinder presses, moving it about during the grinding. The larger kind of saws are suspended at both ends from the top of the mill, to enable the grinder to manage them better, as also to prevent vibration. "It is not easy to conceive the idea of muscular exertion, imminent danger, and peculiarity of attitude presented to the eye and the mind of an individual who, unaccustomed to such a spectacle, looks at a saw-grinder when at work, standing on tip-toes over a great grindstone revolving with a fearful rapidity; his arms outstretched towards the extremities of the board under which lies the saw, and pressing against it with his knees to keep it in the closest contact with the surface of the stone; his person and dress appearing at the same time as if they had been dipped in an ochre bed, present a picture of no common interest."* In point of health and vigour, the saw-grinders contrast most favourably with the fork-grinders hereafter to be noticed. Their employment renders them liable to frequent accidents; but the wet stone being invariably used, no metallic dust is liberated, so that there is nothing injurious to life in the employment.

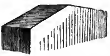
This grinding has materially impaired the flatness and elasticity of the saw; it is therefore planished a second time to restore its flatness, and then held over a coke fire until a slight degree of oxidation, indicated by a faint straw colour, is produced, which restores the elasticity. It is next passed lightly over the grindstone in the direction of the length of the saw, to remove the marks of the hammer; and then smoothed upon a hard smooth stone. It is lastly polished upon a *buff* or *glazer*, the buff being a round wheel covered with leather, which, just before being used, is rubbed over with a cake composed of emery and suet, or bees' wax: the glazer is composed of

---

* Cabinet Cyclopædia:

numerous segments of hard wood, and produces a higher polish than the leather head: this is called glazing on the *hard head*. As this polishing again disturbs the flatness and elasticity of the saw, it is once more planished, or *blocked* as it is now called, with a small polished hammer, upon the end of an upright post of hard wood. The saw is next *cleaned off* by women, with coarse emery rubbed on with a piece of cork, which produces an even white tint and a very level appearance.

The saw would now appear to be entirely finished, and to require only a handle to fit it for use; but at this stage of the manufacture is introduced one of those delicate and curious processes which excite so much surprise when witnessed for the first time. The teeth of the saw have to be *set;* that is, every second tooth, or one half of the teeth, have to be bent a little on one side, and the other half a little on the other side, so as to form an acute angle with either surface of the saw. This is necessary to prevent the teeth from becoming choked up with sawdust, and also to give sufficient breadth to work the saw, the kerf or cut made by it being thus wider than the thickness of the blade. The softest wood requires the widest or *rankest* set. The setting is done by an experienced workman, who places the teeth upon the edge of a small anvil shaped thus, and with a very light hammer runs along the row, striking every alternate tooth so as to bend it a little; he then turns the saw over and strikes every alternate tooth on the other side. In this remarkable operation there are many things worthy of notice; the rapidity with which it is performed is surprising, and may be judged of when the writer states that he had great difficulty in counting the blows of the hammer; and yet the workman selects with unerring certainty every *second* tooth, and strikes it with the exact amount of force required to give it the necessary *set* or bend; a



heavier blow would break off the tooth, and a lighter one would produce no effect. Then again, on turning the saw over, what precision of hand and eye are required to strike a firm blow on every tooth between the teeth which have been already set, striking those and missing these; for if the latter were to be struck, not only would the work be undone, but the tooth would probably fly off in consequence of the hardness of the metal.

SETTING THE TEETH.

The saw is next placed in a vice in contact with two pieces of lead to prevent vibration, and the teeth are filed up sharp. It is once more held over the fire for the purpose of hardening; the thin film of oxide is washed off with a weak acid, and at length the saw is ready for handling. The handles are usually formed out of a plank of beech: the patterns being first drawn upon this plank, it is placed in a vice, and each handle cut out with a hand-saw, holes being drilled where necessary for introducing the saw. When the shape is thus cut out, and the holes for the screws have been pierced, the handle is worked up with different kinds of files and rasps, and lastly polished with whale fin and a bone burnisher. Those saws which require backs are furnished with them at the same time that the handles are fitted on. The back plate consists of a piece of iron folded together so as to form a groove which clasps the back of the saw like a spring.

THE

MANUFACTURE OF CUTLERY.

In the earliest ages of the world, as among rude nations at the present day, shells, flints, and sharp-edged stones were used as cutting instruments. The stone *celts*, so frequently found in the barrows of our own island, formed the knives of the ancient Britons. The ancient Greeks and Romans made their warlike weapons and other instruments chiefly of brass or bronze, and it is probable that the sacrificing instruments mentioned in Scripture were often of the same material. The use of iron and steel was known at an early period; but brazen instruments being more easily fabricated than those of iron, were in more frequent use.

The introduction of cutlery into England is uncertain. Long before the time of Henry VIII. we had an import trade in knives, as appears from the custom-house rate books. In the fifth year of Queen Elizabeth's reign this import trade was restricted, with a view to encourage the home manufactures. At that time London was the principal mart for the finer species of cutlery; but Salisbury, Woodstock, Godalming, and Sheffield, also carried on a considerable trade. According to Stow, "Richard Matthews, on Fleet Bridge, was the first Englishman who attaigned the perfection of making fine knives and knive hafts;" and after mentioning the prohibition of Elizabeth against the import trade, the Chronicler adds, that "at that time, and for many hundred yeeres before, there were made, in divers parts of this kingdome, many coarse and uncomely knives." In 1417 the

London cutlers obtained a charter of incorporation from Henry V. They still maintain a Hall in Cloak Lane, and admit freemen on payment of a livery fine of 10*l.* Long before the date of this charter Sheffield had become celebrated for its knives: thus Chaucer states of the miller of Trompington:—

"A Shefeld thwytel bare he in his hose;"

the instrument here mentioned being a case-knife, or whittle, used for cutting food as well as for various other purposes. The cutlers within Hallamshire (as the district about Sheffield is called) were not incorporated until 1624; but special rules for the government of the craft are extant in the Manor Court-roll, dating from a much earlier period. The incorporation was founded upon an "Act for the good order and government of the makers of knives, sickles, shears, scissors, and other cutlery wares in Hallamshire and parts near adjoining." An important proviso of this Act requires "all persons engaged in the said business to make the edge of all steel instruments, manufactured by them, of steel, and steel only; and to strike on their wares such mark, and such only as should be assigned to them by the officers of the company." These corporation marks have been in some cases of great value, as affording a guarantee of the superiority of the wares upon which they are stamped. They are protected by law, and the forging or imitation of them renders the offending party liable to legal proceedings. The most respectable houses still preserve their name and corporation mark, and refuse to put any other on their wares; but, unfortunately, the practice is not uncommon for manufacturers to stamp on their goods the name of their customer, that is, the retail dealer, instead of their own; and also to mark common iron knives with the words "shear steel," or "cast steel," or "patent," a piece of dishonesty which we regret to see so common.

Table forks are of comparatively modern invention. "I have, I know not how," says Beckmann, "a great unwillingness to represent the tables of our ancestors as without forks; yet this was certainly the case; and when we reflect on their manner of eating, it will readily be perceived that they could much easier dispense with the use of them than we can. All their food, as is still customary in the East, was dressed in such a manner as to be exceedingly tender, and therefore could be easily pulled to pieces. It appears, however, that people, though not in the earliest periods, employed the same means as our cooks, and suffered meat to lie some time that it might be easier dressed. We often read that cooks, in order to provide an entertainment speedily, will kill an animal, and having cleaned and divided it, roast it immediately and then serve it up to their guests. But it is well known that the flesh of animals newly killed, if cooked before it has entirely lost its natural warmth, is exceedingly tender and savoury, as we are assured in many books of travels.

"Formerly all articles of food were cut into small morsels before they were served up; and this was the more necessary, as the company did not sit at table, but lay on couches turned towards it, consequently, could not well use both their hands for eating. For cutting meat, persons of rank kept in their houses a carver, who had learnt to perform his duty according to certain rules, and who was called *scissor, carpus, carptor*, and by Apuleius is named *diribitor*. This person used a knife, the only one placed on the table, and which in the houses of the opulent had an ivory handle, and was commonly ornamented with silver.

"Bread also was never cut at table. In former times it was not baked so thick as at present, but rather like cakes, and could easily be broken; hence mention is so often made of the *breaking of bread*. Juvenal, when he wishes to describe old bread, does not say that it could not be cut, but that it could not be broken. The ancient form of bread is still retained in the paschal cake of the Jews."

The learned professor just quoted refers the first use of forks to the Italians towards the end of the fifteenth century. He quotes a passage from an Italian writer, resident at the court of Matthias Corvinus, King of Hungary, who reigned from 1458 to 1490, from which it appears that in Hungary at that time "forks were not used at table, as they were in many parts of Italy, but that at meals each person laid hold of the meat with his fingers, and on that account they were much stained with saffron, which was then put into sauces and soup. He praises the king for eating without a fork, yet conversing at the same time, and never dirtying his clothes."

There is a curious passage concerning the use of forks in the "Crudities" of Thomas Coryate, who visited Italy in 1608. He says:—"I observed a custom in all those Italian cities and towns through the which I passed, that is not used in any other country that I saw in my travels, neither do I think that any other nation of Christendome doth use it, but only Italy. The Italian, and also most strangers that are commorant in Italy, do always at their meals use a little fork when they cut their meat. For while with their knife, which they hold in one hand, they cut the meat out of the dish, they fasten their fork, which they hold in their other hand, upon the same dish; so that whatsoever he be that sitting in the company of any others at meal, should unadvisedly touch the dish of meat with his fingers from which all at the table do cut, he will give occasion of offence unto the company, as having transgressed the laws of good manners, insomuch that for his error, he shall be at least brow-beaten, if not reprehended in words. This form of feeding, I understand, is generally used in all places of Italy; their forks being for the most part made of iron or steel, and some of silver, but these are only used by gentlemen. The reason of this their curiosity is, because the Italian cannot by any means endure to have his dish touched with fingers, seeing all men's fingers are not alike clean. Hereupon, I myself thought good to imitate the Italian fashion, by this forked cutting of meat, not only while I was in Italy, but also in Germany, and oftentimes in England since I came home, being once quipped for that frequent using of my fork by a certain learned gentleman, a familiar friend of mine, one Mr. Lawrence Whitaker, who in his merry humour doubted not to call me at table *furcifer*, only for using a fork at feeding, but for no other cause."

According to Dr. Johnson the Scotch Highlanders previous to the revolution used neither knives nor forks at table; but every man had a knife of his own as a companion to his dirk or dagger. The men cut the meat into small morsels for the women, who then put them into their mouths with their fingers.

The reputation which Sheffield has so long enjoyed for the manufacture of knives and forks and the various articles of cutlery still continues, and there is not a more acceptable present which an Englishman travelling on the Continent can make than a Sheffield penknife, or pair of scissors. The frequent disputes between masters and men on the subject of wages have certainly had the effect of injuring the cutlery trade, both at home and abroad, by causing doubt and uncertainty in the market. For example, various articles of cutlery are sold from patterns, stitched on cards with the prices annexed; "and as the spirit of competition requires that these terms be adjusted very nicely to a scale of small profit on quick returns, it often happens that before a set of pattern cards with new prices can reach America, or have begun to circulate there, some alteration takes place at the seat of manufacture, and other cards and corrections must be sent out, so that the suspicions, uncertainty, and annoyance of the foreign merchant, all act as a discount upon the integrity of the British manufacturer; the latter, meanwhile, often being nowise to blame for the fluctuations of which, in common with his customer, he is the victim."

The various articles which come under the denomination of cutlery, are, or ought to be, manufactured wholly of steel—at least, as far as the working parts of each instrument is concerned; unfortunately, however, the rage for cheapness on the part of the customer, or some other motive less honourable on the part of the maker, causes common pig iron to be used in the production of knives, forks, razors, and many other articles of cutlery. An iron knife has its uses, however inferior to steel; but an iron razor is absolutely worthless, and is made for no other purpose than *to sell.* At all respectable houses, however, steel is used, either common, shear, or cast. Shear steel, which is very plastic and tough, is used principally for edged tools, which require great tenacity without much hardness, such as table knives, scythes, plane-irons, &c. Articles requiring a very fine polish ought to be of cast steel, such as razors, scissors, pen-knives, &c. As cast steel can be welded to iron with great facility, the cutting part of chisels, plane-irons, &c. is formed thereof, and the rest of the tool of the inferior metal.

In the production of a table-knife, the blade is first rudely forged from a bar of shear steel, and then cut off: it is next welded to the extremity of a rod of iron about half an inch square, and a portion of this is cut off sufficient to form the bolster or shoulder together with the tang. The proper size and shape are given to the bolster by introducing that part of the metal where they are intended to be raised into a die on the anvil; a hollow mould or *swage* is then put upon it, and a few smart blows are given by the striker. The blade is next heated a second time and properly finished on the anvil; this is called *smithing* the blade. The maker's mark is stamped on, and the blade is ready for hardening, which is done, as usual, by bringing it to a red heat and plunging it perpendicularly into cold water. It

FORGING TABLE-KNIVES.

is tempered to a blue colour, and then sent to the grinder.

In all details respecting the manufacture of steel goods frequent mention must be made of the important processes of *hardening* and *tempering*. The useful property of steel of becoming hard by raising it to a red heat and suddenly cooling has already been noticed. But as the hardness thus imparted is accompanied by great brittleness, the steel is again heated, but to a much less degree; in proportion, however, as the heat is increased, the hardness diminishes, and when reduced to the proper degree of hardness required by the instrument, it is again suddenly cooled by plunging it into cold water or other fluid. But it will be asked, how is this proper degree of hardness to be judged of? The test is a very beautiful one. When steel is slowly heated in the air to a temperature of not less than 430° oxygen combines with it, producing a thin film of coloured oxide, and experience has pointed out the particular colour which gives the temper required for the tool or instrument under operation. When elasticity is required, as in springs for watches, gun-locks, &c., the steel is cooled as soon as it has assumed a fine blue. When a keen edge is required, as in razors, the edge is brought to a fine straw colour, while the back is blue. The respective temperatures at which these effects take place, were ascertained by Mr. Stodart, and are given in the following table:—

1. Very pale straw yellow	430°	The temper required for lancets.
2. A shade of darker yellow	450	A little softer for razors and surgical instruments.
3. Darker straw yellow	470	Pen-knives.
4. Still darker straw yellow	490	Chisels and shears for cutting iron.
5. A brown yellow	500	Axes and plane-irons.
6. A yellow, tinged slightly with purple	520	Table-knives and cloth-shears.
7. Light purple	530	Swords and watch-springs.
8. Dark purple	550	
9. Dark blue	570	Small fine saws.
10. Paler blue	590	Large saws, whose teeth require setting with pliers and sharpening with a file.
11. Still paler blue	610	
12. The same, with a tinge of green	630	Too soft a temper for steel instruments.

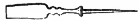
That the presence of oxygen is necessary for the production of these colours was proved by Sir Humphrey Davy, who heated bright polished steel in an atmosphere of nitrogen and no colorific effect was produced.*

To return, however, to the forging of knife-blades. The size and shape of these vary according to the purposes for which they are required; the shoemaker's knife, the bread-knife, &c., are forged in the same way as the table-knife. The pen-knife blade, which ought to be of the best cast steel, is forged with a light hammer upon a small anvil from the end of a steel rod, and as much cut off as is necessary to form the joint. The blade is then held in a pair of tongs, and heated a second time; the joint part is next finished, and a temporary tang drawn out for driving into a small haft used by the grinder. the nick or notch, called the *nail-hole*, used in opening the knife, is made while the blade is hot, by stamping upon it a chisel edge of the required shape. The blade is hardened by raising it to a red heat and dipping it in water up to the shoulder. The tempering is performed by setting a number of blades side by side with the back downwards upon a flat iron plate, placed over the fire, and allowing it to remain until the blades assume the proper colour.

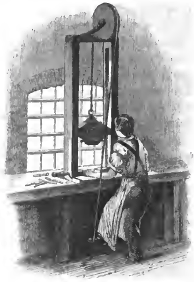
---

* According to Nobili, the colours produced on steel by heat are not due to the union of oxygen with the metal; but the oxygen by combining with the carbon in some manner becomes fixed in the form of a thin plate or film, which has the effect of preserving the metal from rust. If this tint were the effect of oxidation, he thinks it would, instead of preventing, serve only to accelerate oxidation. In order to show the preservative effect of this film, Nobili took two steel plates of the same quality and polish. He coloured one by the ordinary process, and exposed both in the open air to all the vicissitudes of a rainy autumn. At the end of a month the uncoloured plate was all rusted; the other had lost a little of its colour, but was free from rust.

Forks are occasionally made of cast metal, but the better kinds are forged from a rod of steel, about three-eighths of an inch square: the tang, shoulder, and shank are first roughly formed, and then cut off, leaving at one end about an inch of the square part of the steel, which is afterwards drawn out flat to about the length of the prongs. This *mood* or *mould*, as it is called, is shown in the annexed cut. It is heated till soft, and placed red hot in a steel boss or die, upon which a second boss, connected with a heavy block of metal, is made to fall from the height of several feet: this forms the prongs and central part or *bosom* of the fork, leaving between the prongs only a thin film of steel, which is cleaned out with a file. The fork is then ground and burnished, and is ready for hafting.



This method of stamping is very common in



STAMPING FORKS.

the manufacture of plated goods. The stamp is fastened to one end of a rope, which is passed over a trundle at the top of the frame; to the other end of the rope is a stirrup in which the workman places his left foot, raises the stamp to the required height, and then suddenly allows it to fall. Forks with four or five prongs, called *spoon-forks*, and silver and plated forks are commonly formed by stamping, the spaces between the prongs being afterwards cleared out, and the redundant metal cut away.

Razor blades ought to be forged from bars of the very best highly carbonated cast steel, tilted to about half an inch in breadth, and of a thickness sufficient for the back of the razor. The blade is first moulded by the hammer at the extremity of the rod; and the edge being brought out, the concavity is formed by working the material on the rounded edge of the anvil: it is then chopped off and the tang or tongue either drawn out from the same material as the blade, or if this be of very superior quality, a piece of iron is welded to it for the purpose. "As there is generally such a large disproportion between the thickness of the back and the edge, the steel ought to be of an excellent quality, in order to allow of the beating necessary to produce the thinner part. Some workmen are so expert in accomplishing this, that they will produce on the anvil an edge so sharp and even that whetting alone will be required to prepare the blade for the purpose of actual shaving." After the blade is cool it ought to be well *smithed*—that is, beaten on an anvil to make the metal as compact as possible; a remark that applies to all the better kinds of cutting instruments.

The shape of the blade is variously formed, according to the taste or fancy of the purchaser. The edge may be straight or convex; the blade may be broader at one end than at the other, and *vice versâ;* but these are points of far less importance than goodness of material and perfect temper. Instead of hardening the blade after the forging, it should first be slightly ground, not only to bring it nearly to the shape required, but also to remove the scale or coating, which prevents the uniform application of water and heat in hardening and tempering. These processes require to be conducted with the greatest nicety, and are generally left to the man who forges the blade.

While on the subject of forging articles of cutlery, some notice may be expected of scissors, an article which varies in price as much as any other piece of cutlery; for while some are sold at the wonderfully low rate of threepence-halfpenny per dozen pair, others produce ten guineas and upwards the single pair; and between these two extremes the prices are very numerous, according to the value of the metal and the amount of labour bestowed upon the handles. The best scissors are made of cast steel, and are hardened in the blades, shanks, and bows. In shear-steel scissors, which are in most common use, the blades only are hardened. A third variety, called *shot* scissors, have steel blades, but the bows and shank are of iron. Large scissors, such as tailors' shears, are of this kind; but when steel was a more costly substance than it is at present, it was common to make all the larger sizes entirely of iron, with the exception of a slip of steel welded along the edge of the blade. The best description of *iron* scissors are improperly called *run* or *virgin steel:* they are formed of good cast iron; while the cheapest description of scissors are made of common cast iron in prodigious quantities for South America and the Indies. The most costly scissors have their shanks and bows of gold, silver, &c.

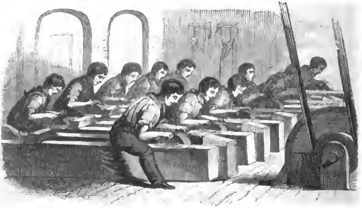
Steel scissors are forged from a bar of the required size, and when a single blade is formed it is cut off, together with enough of the metal to form the shank and bow. A hole is then punched through the projecting lump of metal, sufficient to admit the point of a small anvil, called a *beck-iron.* The bow is formed upon this by hammering. After being lighted or softened in the fire, the shank and bow are filed into better shape, the joint is squared, and the hole bored and fitted for the rivet. The blades are next ground; after which the bows and ornamental work are smooth-filed and burnished with fine emery and oil. As the blades are forged chiefly by eye, and without reference to their being in pairs, a workman now takes a number of separate blades, sorts them into pairs, screws them together, and makes them *walk and talk* well, as the workmen call the smooth motion of the blades against each other. They are next bound round with fine iron wire, the rivet is taken out, and the blades and shanks are hardened in the usual manner. When the wire is removed they are ground into proper shape, again fastened together, and made to work properly. The bows and other parts are rubbed up with fine emery and oil, and the scissors are taken a third time to the grinder, where the shanks are ground and the whole instrument glazed and polished. Being once more put together, and the edges of the blades whetted, the scissors are handed over to women, who carefully fine-burnish the parts requiring it with polished steel tools.

The screw which unites the two scissor-blades consists of three parts, differing in diameter, namely, the *head*, the *neck*, and the *thread;* while the bottom of the hole or countersink, which receives the head of the screw, is called the *shelf*, or *twitter-bit*. On holding a pair of closed scissors edgeways to the light, it will be seen that the blades are not in contact except at the points. The reason for this is not at first obvious. It might be supposed that the blades would be made as flat as possible, so that they might come into close contact. If this were so, not only would the friction be increased where it was not wanted, but the edges would not work together, and it would be scarcely possible to cut with them, as the material would fold in between the blades. Now in order to bring the edges into contact with a certain amount of pressure, the blades are a little curved in opposite directions, so that on holding up an open pair of scissors edgeways they will be seen to overlap. It will further be remarked, that just behind the screw-pin, by which they are united, there is a small elevation or ridge called the *riding-part*, one for each blade. When the scissors are open to their full extent the points only of the riding-part are in contact, and the blades, if shaken, appear to be loose; but on gently closing the scissors, the riding-parts rub more and more against each other, the effect of which is to keep successive por-

Digitized by Google

tions of the edges in contact throughout the length of the cut.

The grinding and polishing of cutlery is carried on at Sheffield for the most part in buildings called *wheels* or *mills.* Each mill is divided into a number of separate rooms, called *hulls,* and in each hull are six *troughs,* with a grindstone and a polisher in each trough. Motion is communicated to the wheels by means of a steam engine. The most celebrated of these grinderies is the Castle mill, situated near the junction of the Sheaf and the Don. Its external castellated appearance has given it a name. It consists of a central court-yard, with buildings running along the four sides, containing numerous apartments occupied by the grinders, who contribute each a certain sum for rent and for steam power. At the time of the writer's visit this mill was closed in consequence of one of those unfortunate disputes between masters and men about prices; but the foregoing sketch was taken from an establishment visited by the writer, where all the processes are conducted on the premises.



GRINDING CUTLERY.

The stones vary in quality and size with the article to be ground. Saws, fenders, &c., which present a large extent of surface, require stones of great diameter; while razors and the smaller articles of cutlery are ground upon small stones. Saws, scythes, and edge tools which require a certain temper, are ground on a wet stone, for which purpose water is kept in the trough to such a height as just to touch the stone. An extensive class of small articles, such as razors, scissors, pen and pocket-knives, forks, needles, &c. are ground upon a dry stone. Dry grinding is a more expeditious operation than the wet, but several articles of cutlery are first ground on a dry stone, and afterwards on a wet one. Fork grinding, however, is always performed on a dry stone, and hence the peculiarly destructive character of this branch. Dr. Holland,* a physician of Sheffield, declares the fork grinder's employment to be probably more destructive to human life than any other pursuit in the United Kingdom. "In the room in which it is carried on there are generally from eight to ten individuals at work, and the dust which is created, composed of the fine particles of stone and metal, rises in clouds, and pervades the atmosphere to which they are confined. The dust which is thus every moment inhaled, gradually undermines the vigour of the constitution, and produces permanent disease of the lungs, accompanied by difficulty of breathing, cough, and a wasting of the animal frame, often at the early age of twenty-five. Such is the destructive tendency of the occupation, that grinders in other departments frequently refuse to work in the same room, and many sick clubs have an especial rule against the admission of dry grinders generally, as they would draw largely on the funds, from permanent and long-continued sickness."

It is shown from the statistics of the trade, that the average age of fork grinders does not exceed thirty years, and Dr. Holland shows that while in the United Kingdom 296 persons out of 1000 die annually between the ages of 20 and 40, 885 fork grinders perish out of the 1,000!

---

* The works from which our information on this subject has been chiefly obtained are:—

The Vital Statistics of Sheffield, by G. Calvert Holland, Esq., M.D., London, 1843.

Diseases of the Lungs from Mechanical Causes, by the same, 1843.

A complete remedy for the evil consists in the thorough ventilation of the fork grinder's apartment by means of the revolving fan already referred to.* It consists of a wooden funnel from ten to twelve inches square placed a little above the surface of the revolving stone, on the side the farthest from the grinder, which funnel terminates in a channel immediately under the surface of the floor. The channel varies in length according to the situation of the grinder in reference to the point where it is most convenient to get quit of the dust. If we suppose that eight or ten grinders work in the same room, each has his own funnel and channel, as shown in the cut at page 54, and they all terminate in one large common channel situated close to the wall of the apartment. Within this general channel is placed a fan similar to that used in winnowing corn, and to this is attached a strap (also shown in the cut) which passes upwards and over a pulley, so that whatever puts the pulley in motion, causes the fan also to revolve. The pulley is placed in connexion with the machinery which turns the stone, so that whenever the grinder adjusts his machinery to work, he necessarily sets the pulley and the fan in motion. The fan acting at this point, whatever may be the length of any of the subordinate channels, causes a strong current to flow from the mouth of each funnel, which carries along with it all the gritty and metallic particles evolved, leaving the room in which the operations are pursued free from any perceptible dust. When the whole apparatus is perfect and in excellent condition, the atmosphere of the place is almost as healthy as that of a drawing room.

---

* See ante, p. 8.

Dr. Holland mentions that in one manufactory, the dust is conveyed by the general channel into a trough of water outside the building. The quantity which accumulates in it in a few weeks is very great; and in raising it in a mass, it seems to have almost the specific gravity of metal. The first cost of the apparatus would scarcely exceed the proportion of a sovereign for each grinder; the funnel may be had for a few shillings, and the fan and pulley for a mere trifle. "Were the Legislature to interfere, and make it imperative on the part of the proprietors of wheels to construct such an apparatus, and compel them to keep it in a perfect condition, an immense amount of disease, suffering, and wretchedness would be prevented; and the future inquirer into the condition of grinders would not have to record the numerous premature deaths." In places where the apparatus had been in operation for years, Dr. Holland did not find a single individual labouring under any pulmonary affection; and in other instances where the lungs had become affected with disease, the erection even of an imperfect apparatus by the artizans themselves, arrested the disease, and afforded substantial relief.

In grinding articles of cutlery the size of the stone is of importance. If ground upon a large stone, revolving with great rapidity, the grinding will, it is true, be performed more expeditiously than on a smaller stone moving at the same rate, but the steel is often thereby, by overheating, deprived of some of its excellent qualities, which no subsequent operation can restore. The concavity on the surface of a blade also depends upon the size of the stone: thus a stone four inches in diameter must give to the blade a corresponding concavity, or a curve of two inches, radius; and such a curve will evidently yield a keener edge than can be produced from a six, eight, or twelve-inch stone, because the smaller the diameter the more convex is the stone, and the more concave will be the blade which is ground upon it. Mr. Ebenezer Rhodes, of Sheffield, a practical cutler, in his "Essay on the Manufacture of a Razor," enumerates the qualities of a good razor to consist in a proper form, weight, and justness of proportion, with proper hardness, regularity, and fitness of concavity. The stones used in producing this concavity of surface vary from four to twelve inches in diameter, according to the price of the article required. A four-inch stone is most generally used; but Mr. Rhodes recommends a stone of from six to eight inches in diameter, which produces razors "sufficiently hollowed or ground out for any service, however hard, to which they may be applied; and they combine a desirable strength and firmness of edge with a requisite degree of thinness. The concavity of a razor should likewise possess great evenness and regularity, otherwise a very unequal edge is produced; a defect which every application to the hone will rather increase than diminish, and which nothing but re-grinding in a more perfect manner can possibly remove."

The grinders usually have some contrivance to protect their hands from the great heat excited by the friction, and also to enable them to hold the article properly to the stone. Table-knives are fitted in a wooden case, shown in the following engraving:—

Glazing is the next process to grinding. The glazer or *lap*, as the workmen call it, is a circular piece of wood formed of a number of wedges, the thin ends of which meet in the centre. It moves upon an iron axis, similar to the grindstone, but with much greater rapidity. There are various glazers, in some of which the bare wooden surface is used, while others are faced with leather, or with an alloy of lead and tin. The leather-faced glazers, which are used for forks, table-knives, and edge tools, and all the coarser polished articles, are coated with a paste composed of glue and emery. The other glazers are coated with tallow and emery. From the rapidity with which the glazer moves, a stream of sparks is produced, and unless great care be taken by the workmen, there may be sufficient heat to *blue* the article, the effect of which is frequently to destroy the temper of the blade.

After glazing, the blade is polished on the *buff* or *polisher*, and the rich black lustre peculiar to fine steel goods is produced by this process. The buff is a solid wheel covered with thick soft leather and dressed with crocus of iron. It runs much slower than either the lap or the grinding stone.

An important part of the cutler's business consists in handling or hafting the various articles of cutlery. The materials with which handles are made are very various, from stamped gold and silver to the commonest cast iron and wood. But the material most used for this purpose is ivory, both of the elephant and of the walrus; German and Indian stag horn, buffalo and cow horn, tortoiseshell, mother-of-pearl, coco wood, snake wood, &c., are also in request. The best method of attaching handles to articles in such common use as knives and forks is to nail flat pieces of bone, ivory, or wood, upon a flat piece of iron continued from the blade; the next best method is to drill a hole completely through the handle, and to insert a cylindrical or four-sided prong projecting from the blade, riveting it at the opposite end: this is called *through-tang*. But the most common method is to pass the small prong projecting from the blade about half-way into the handle, securing it with melted resin, mixed with fine ashes, or with whiting, for improving the colour. A knife thus hafted comes apart when put into hot water, or is otherwise exposed to heat. Balance handles are made by perforating the haft deeper than usual and then dropping in a small piece of lead; the blade being made with a projecting shoulder near the handle, the knife rests upon the handle and shoulder without touching the table-cloth.

In the hafting of table knives and forks the consumption of ivory is immense. The teeth are cut up by means of a small circular saw; a strong offensive ammoniacal odour being produced during the operation. Stag horn handles are boiled, to soften them and make them straight; but in the German stag horn, the friction of the file in working them produces sufficient heat for the purpose. The cow horn used for razor handles, &c., is pressed, by means of heat, into iron moulds of the size and shape required for one side of a razor handle, and is then dyed black, or stained in imitation of tortoiseshell.

PREPARING IVORY HANDLES.

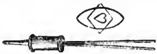
It would be tedious to go through all the processes required for completing an ordinary article of cutlery. They are, perhaps, most numerous in a common penknife; one with three blades having to pass through the finishers' hands at least a hundred times. When

Digitized by Google

the blades, spring, and scales are severally bored with appropriate holes, they are all pinned together, loosely at first, till all the parts fit and work properly together; they are then riveted with bits of wire with a hammer on a small anvil. If the sides are of horn, ivory, or shell, they are filed smooth and scraped, and afterwards polished twice on the buff. The first, which is called *rough buffing*, is with Trent sand; and the second, *gloss buffing*, with oil and rottenstone. The backs of the springs are glazed on the glazer, or polished with a steel burnisher.

CUTLERY WORKSHOP.

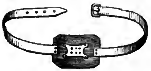
The shield or plate of silver for one side of the handle is cut out by a moveable type punch, and inserted in a curious manner. The cavity in the handle is cut out with a spring piercer, or double drill, consisting of two elastic steel blades, sharp at one end. A plate of steel, perforated according to the required shape of the shield, is placed on the handle; in this perforation the two sharp ends of the drill are held and made to revolve by the boring stick. The effect of this



Digitized by Google

revolution is to coil the springs round each other, while their elasticity forces them asunder; and in doing so, they describe a small number of circular arcs; and as the workman is constantly moving these points over every part of the circumscribed space, a cavity is soon cut out to the required depth. The plate, or shield, is then driven in, and is held in its place by two pins projecting from the under surface.

The usual method of boring holes is with *piercers*, or *parsers*, of different sizes, made of the best steel, and passed through a small wooden cylinder. Motion is given to this by means of the *boring-stick*, which is a hazel wand, about 30 inches long, to the ends of which is fastened a leather thong, sufficiently slack to admit of being twisted round the cylinder of the piercer. The short blunt end of the piercer is held against a *breast-plate*, which is strapped round the workman's body. The breast-plate is furnished with a steel boss, containing holes of various sizes, for receiving the blunt end of the piercer. While this rests in the breast-plate, and the loop of the thong of the boring-stick embraces the cylinder, the sharp end of the piercer is pressed against the work to be drilled, and rapid motion is given to the piercer by moving the boring-stick backwards and forwards. In this way holes of the required size are soon drilled.



RAILWAY-CARRIAGE SPRINGS.

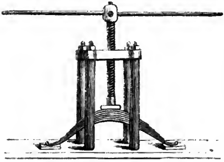
The great extension of our railroad system has introduced new features into many departments of the useful arts, among which may be mentioned the manufacture of railway-carriage springs, which is extensively carried on at Sheffield.

It is scarcely necessary to state that a carriage spring consists of a number of curved steel plates of lengths gradually increasing from the top plate, which is the shortest, to the bottom or longest plate. They are held together by a pin, passed through the centre of the whole series, and are kept in their places by bolts midway between the centre and the extremities, arranged in slits, in such a way as to allow the plates a certain amount of motion upon each other. The number of plates in one spring varies from seven to nine for a first-class carriage spring; from twenty to twenty-five for one of the six springs required in a locomotive. The steel employed is of mild conversion, that is, the bars are not kept so long in the cementing furnace as in many other cases. These bars are rolled into sheets of from a quarter to half an inch thick, and the form of the spring plates is chalked out upon the sheets, much in the same way as a tailor chalks out his patterns on a piece of cloth. The plates are then cut out with a pair of strong

BENDING SPRINGS.

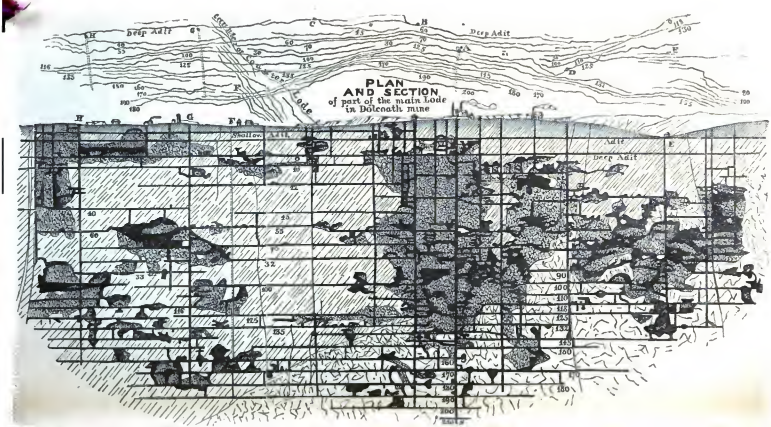
shears. They vary in breadth from two and a half to four inches.

When the plates are cut out, they are of equal thickness throughout; the holes are punched out for fitting the bolts, and the plate is then forged into the proper shape. While at a red heat it is fixed in a vice, and the proper curve given to it by hammering it upon a mould, or simply by bending, as shown in the engraving. When cold, each plate is filed into shape; it is thinned off towards the extremities, and otherwise finished: then come the usual processes of hardening and tempering; after which the number of plates required for one spring are fitted together, and the temper of the spring tried in a screw-press. The spring is placed on its two extremities, as shown in the annexed engraving, and a chalk mark made against one of the upright posts to correspond with the highest part of the curve: the spring is then screwed down until it becomes quite flat, and, on relieving it of this pressure, it is expected to rise up again to within one eighth of an inch of the chalk mark. It is calculated that the testing force of this screw, as applied to passenger-carriage springs, is about five tons; and for locomotive springs, about twenty tons.



TESTING SPRINGS.

In the years 1856, 1857, and 1858, the quantities of hardware and cutlery exported from the United Kingdom amounted to 694,763 cwts., 786,776 cwts., and 661,889 cwts., respectively; of the declared values of 3,747,598*l.*, 4,016,230*l.*, and 3,280,466*l.*, respectively. The United States of America took the largest quantities; Australia the next largest.



PLAN
AND SECTION
of part of the main Lode
in Dolcoath mine

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF COPPER, TIN, LEAD, AND ZINC.

The British Islands, as regards their mineral riches, occupy a foremost rank among the countries of Europe. Cornwall, Derbyshire, and Cumberland are the three mining centres in England. Cornwall furnishes all the tin and seven-eighths of the copper produced in England. The Isle of Anglesea and some other districts in North Wales supply nearly all the remaining copper ore. In Derbyshire lead ore is extracted from the hilly country in the neighbourhood of the Peak. In Northumberland, Durham, and Cumberland, a wide extent of high moorland is intersected by the valleys of the Tyne, the Wear, and the Tees, and their tributaries; and the deep fissures which form these valleys expose numerous veins of ore, chiefly lead. The elevated tracts of Wicklow, Wexford, and other parts of Ireland; the hilly country of Flintshire and other parts of North Wales, and some of the mountain districts of Scotland, are also worked for their mineral produce. The districts which furnish England with the most valuable of her mineral treasures—iron and coal—have been described in former treatises. In the present treatise attention will be confined to those four common metals which rank next to iron in point of importance,—namely, copper, tin, lead, and zinc.

Copper is distinguished by its red colour; it has much lustre; it can be beaten or rolled into sheets, and drawn into wire; it is very tough, and gives out a peculiar smell when rubbed. It melts at a cherry-red, or dull white heat, or, according to Daniell, at a temperature equal to 1996° Fahr. When in fusion, it absorbs small quantities of oxygen from the air, which escape again when the metal solidifies, causing portions thereof to spirt out. At a very high temperature copper boils and emits fumes, which condense upon a cold surface into minute globules of the protoxide, with a metallic nucleus. Copper is between eight and nine times heavier than its own bulk of water, the specific gravity of cast copper being 8.788, and of rolled or hammered copper, 8.958. By long exposure to a damp air, copper becomes covered with a thin greenish crust of oxide and carbonate of copper. When heated, and plunged into water, a number of scales separate; but at a red heat copper does not, like iron, decompose water. Copper derives its name from the island of *Cyprus*, where it was first wrought by the Greeks. It occurs native in various forms. Among its ores the sulphurets are the most abundant, and these, for the most part, supply the commercial demands.

TIN is of a silvery-white colour, with a slight tinge of yellow, which is very apparent when the white light reflected from its surface is excluded. It is malleable, but not very ductile. Tin-foil is obtained by beating out the metal, and is often not more than a thousandth part of an inch in thickness. The specific gravity of tin varies from 7.28 to 7.6. When bent, its particles separate with a crackling noise, and when a bar of tin is held in the hands, and bent rapidly backwards and forwards, it soon becomes too hot to hold. It exhales a peculiar odour when rubbed. It melts at 442°, and contracts slightly on cooling. By exposure to heat and air, it becomes converted into an oxide. The principal ore of tin is the native peroxide. The common ores are called *mine tin*, and *stream tin*, both of which will be noticed more particularly hereafter.

Lead is of a bluish white colour; it is brilliant when the surface is clean; it is very flexible and soft, and leaves a black mark when drawn on paper. It gives out a peculiar odour when handled. It can be rolled into thin sheets, and drawn into wire, which, however, has not much strength. It melts at about 612°, and readily combines with oxygen at a high temperature. It contracts considerably in cooling. Its specific gravity, when pure, is 11.445, but the lead of commerce is seldom more than 11.35. Its specific gravity is said to be not increased by hammering. The sulphuret or *Galena* is the only important ore of lead; from this the metal is chiefly obtained.

Zinc is a bluish white metal, lustrous when pure, rather hard, and of a specific gravity of about 6.8. By drawing into wire, or rolling into plates, its density becomes increased to 7 or 7.2. It emits a peculiar odour when breathed upon or handled with moist fingers. At common temperatures it is tough, and is broken with difficulty by the hammer; but at a temperature a little above that of boiling water (212°) and between that and 300° zinc may be rolled into thin leaves and drawn into wire, which, however, has not much tenacity. It fuses at about 773°, and becomes very brittle as it approaches this point. Zinc is sometimes called *spelter*, in commerce, and it is found in the state of oxide and of sulphuret.

Of these four metals, the first three appear to have been known in very early times, and even to have preceded the use of iron. Zinc in the metallic form does not seem to have been known to the ancients. It is abundant in China, and immense quantities of spelter were formerly imported into Great Britain by the East India Company, for the use of our manufactures; while, at the same time, the ores capable of yielding zinc existed in great abundance in our own island, and were commonly used in Wales for mending the roads. There is, therefore, not much to be said respecting the history of this metal: the history of the other three metals is full of interest, and will occupy a portion of our limited space. The mining operations for extracting the ores are essentially different from those in use in the collieries and in the coal and iron pits already described, and will, therefore, require a somewhat extended notice. The dressing and smelting of the ores are also different. These processes will be described, together with a few examples of manufactures in these four useful metals.

HISTORICAL NOTICE OF COPPER.

Copper was known in the earliest ages of the world, and was applied to a vast number of purposes, to which malleable iron has since been found to be more readily available. In our translation of the Old Testament the word *brass* is frequently mentioned to signify *copper*, or *bronze*, which is an artificial alloy of copper and tin; or *brass*, properly so called, which is an artificial alloy of copper and zinc. Thus in the passage in Deut. viii. 9, which describes "a land whose stones are iron, and out of whose hills thou mayest dig brass," we may suppose either that the word *brass* refers to copper ore, or to the ores of two separate metals, which being reduced, and melted together, form brass. This latter view is rather supported by the statement in Job xxviii. 2, that "brass is molten out of the stone;" and also in Genesis, iv. 22, where Tubal-Cain is mentioned as "an instructor of every artificer in brass and iron," that is, showing how by the union of two metals brass might be produced, and worked up into useful forms.

The metal in most common use in ancient Egypt was bronze. Culinary vessels, weapons, and tools were made of this alloy, specimens of which are preserved in the British Museum. It has been suggested that the "bow of steel" mentioned in Job xx. 24, 2 Sam. xxii. 35, and Psalm xviii. 34, was really a bow of bronze. "The word נחושה, *nachooshah*, which in each of these three passages is infelicitously

Digitized by Google

rendered 'steel' in our version, is everywhere else translated 'brass,' as is the kindred term *n'chosheth* (one of much more frequent occurrence), with the single exception of Jer. xv. 12, where it also is rendered 'steel.'"*

The Hebrews were possessed of considerable skill in the art of metallurgy—a skill which they probably acquired during their long captivity in Egypt. In the time of the Pharaohs, Egypt was supplied with brass—*i. e.* copper, or the ores of two metals capable of forming brass, or bronze,—from the mines of the neighbouring countries of Nubia and Ethiopia. At a much later period Agatharchidas, of Cnydus, who wrote about the year 170 or 180 B. C., states that the abundance of brass (or bronze) was such that it formed the chief part of the domestic furniture, as well as the chariots, the swords, the bows, and the arrows in use in a prior age.

"The general voice of antiquity affirms, that gold, silver, and copper, or brass (æs) were the first metals discovered; and that they were used partly as ornaments, and partly as instruments of war or of industry; for though, from their softness, they were not the best calculated for the latter purposes, they were better adapted to them than those implements of flint or other hard stones, or hard wood, which had been before used by the most ancient tribes, and which were also found among the savage people inhabiting Australia, who were discovered in the middle of the last century.

"A well-known passage in Hesiod affirms that in remote ages 'the earth was worked with brass, because iron had not then been discovered;' and Lucretius bears testimony to the same purpose. This is confirmed by the implements of copper found in the ancient mines of Siberia, and in Nubia, whose working must have ceased some thousand years ago. When Brazil was first discovered by the Portuguese, the rude inhabitants used fish-hooks of gold, but had no iron, though their soil abounded in that metal. The people in Hispaniola and Mexico were in like manner unacquainted with iron when first visited by the Spaniards; though they had both ornaments and implements of gold, and weapons of copper; which latter, as we learn from the analysis of Humboldt, they had acquired the art of hardening by an alloy of tin, or, in other words, of converting copper into *bronze.*

---

* The Monuments of Ancient Egypt. By P. H. Gosse.

"This subject has been illustrated in Denmark by opening many Scandinavian tumuli of very remote ages, from which have been collected specimens of knives, daggers, swords, and implements of husbandry, which are preserved and arranged in the Museum at Copenhagen. There are tools of various kinds, formed of flint or other hard stone, in shapes resembling our wedges, axes, chisels, hammers and knives, which are presumed to have been those first invented. There are swords, daggers, and knives, the blades of which are of gold, whilst an edge of iron is formed for the purpose of cutting. Some of the tools and weapons are formed principally of copper, with edges of iron; and in many of the implements the profuse application of copper and of gold, when contrasted with the parsimony evident in the expenditure of iron, seems to prove that at the unknown period, and among the unknown people who raised the tumuli which antiquarian research has lately explored, gold, as well as copper, were much more abundant products than iron."*

The writer just quoted goes on to say, that copper in the more remote ages was not only commonly, but in some, if not in all, exclusively, used for money; and at those periods may be viewed as one of the precious metals, although, in later times, gold and silver have become more especially entitled to that name.

Swords and celts, apparently formed of an alloy of copper and tin, have been dug up in Ireland, and brazen weapons of ancient formation have also been found in this country. These are supposed by Camden to be of British manufacture, but on this subject all is conjecture. The earliest inhabitants of Britain, of whom we have any authentic account, wore massive rings, probably of copper or brass, upon their arms and legs, but whether of native manufacture, or imported, is not known.* According to the statement of Cæsar, the Britons made use of imported copper.

---

* JACOB, History of the Precious Metals.

Copper occurs associated with other mineral strata in several parts of this country. Previous to the year 1770, large quantities of the ore were obtained from the Duke of Devonshire's mine, at Ecton, in Staffordshire, but the main body of the mineral at that place has long been exhausted. The chief source of our copper ore is Cornwall, a country which, during so many ages, was celebrated for its valuable tin ore. This being found much nearer the surface than copper ore, naturally attracted attention, while the copper was overlooked, until increased skill in mining revealed its value and abundance. In the fifteenth century a few mines were worked in an imperfect manner, and for a long period the persons who raised the ore were so little aware of its value, that the merchants to whom they sold it gave a price for it far too low. In the reign of James I. however, the mines were worked with more skill and profit to the proprietors. This change appears to have been brought about by Mr. Norden, Cornish surveyor to the Prince of Wales, who, having observed that the real value of the ore raised from the mines was concealed, wrote to the king a statement of the frauds, and recommended means for their prevention. The political confusion of the subsequent reign interfered with the prosperity of the copper mines, but after the Restoration, a company of Bristol merchants visited them, and agreed to purchase the produce, at prices varying from 50*s.* to 80*s.* per ton. The bargain proved so advantageous to the merchants, that another set of Bristol merchants agreed with some of the principal Cornish miners, to purchase their ore at a stated low price for a certain term of years. This competition naturally led the miners to attach greater importance to their commodity, but it is a curious proof of their ignorance, that the valuable yellow copper ore was at this time rejected by them as worthless mundic, and thrown aside as refuse.

---

* Bronze rings of this kind were actually found round the wrists of a skeleton dug up a few years since at the earth-work near Lower St. Columb Porth. They have also been discovered in old tin-stream works, probably lost by the persons employed in them. A circle of brass, six inches in diameter, inlaid with gems, was found in Trenoweth stream-work, in 1802.

The flourishing state of the copper trade in the reign of Queen Anne is evident from a statute then passed. It appears that in the 13th and 14th years of the reign of Charles II. an act was passed allowing the exportation of copper bars imported from foreign parts, and a drawback of all duties was allowed on such exportation. In the act of Anne it was stated that "forasmuch as the copper manufacture of this kingdom is brought to such perfection that there is more made than can be expended here and in the plantations," it was consequently enacted, "that no drawback be allowed on the exportation of any copper but such as shall be imported from the East Indies and the coast of Barbary only."

From this time the history of the copper trade is one of gradually increasing prosperity, occasionally checquered by reverses, arising from the supply of the metal being greater than the demand. During the war, large quantities of copper from South America were taken by the British cruisers and brought to England; and, about the same time, considerable importations of copper from South America were made, whereby the home trade suffered considerably.

In the year 1775 the quantity of copper ore raised in Cornwall did not amount to 3,600 tons, and its value was 192,000*l.* At the commencement of the present century it had increased to upwards of 5,000 tons, and its value was then nearly half a million of pounds sterling. A quarter of a century later the supply was upwards of 8,000 tons, and its value was 750,000*l.* In 1838, 11,527 tons of copper were obtained from 145,688 tons of ore, the value of which was 857,779*l.* The following Table will supply some further particulars respecting the copper produced from the Cornish mines:—

Years ending in June.	Quantity of Ores in Tons of 21 Cwt.	Metal or Fine Copper.		Value of the Ores.	Produce of Ores per Cent.	Average Price per Ton.		
		Tons.	Cwt.	£		£	*s.*	*d.*
1839	159,551	12,450	18	932,297	7¾	109	3	0
1840	147,266	11,037	16	792,758	7½	108	10	0
1841	135,090	9,987	2	819,949	7⅜	119	6	0
1842	154,180	9,896	3	822,870	7⅛	120	16	0
1845	162,557	12,883	3	919,934	7⅞			
1846	150,431	11,850	14	796,182	7⅞			
1847	155,985	12,754	0	889,287	8½			

In 1842 the quantity of unwrought copper exported amounted to 53,446 cwt.; of copper coin, 210 cwt.; of sheet copper, nails, &c. 130,848 cwt.; of copper wire, 64 cwt.; of wrought copper of other sorts, 9,493 cwt. In this year the quantity of copper smelted from foreign ores in the United Kingdom was about equal to the quantity of British copper exported.

By the Customs regulations, old copper sheathing and utensils, and old copper and pewter utensils of British manufacture imported from British plantations, and also old copper stripped off vessels in ports in the United Kingdom, are admitted duty free under certain regulations.

Copper is in extensive demand all over India; it is largely used in the dock-yards, in the manufacture of working utensils, in alloying spelter and tin, &c. The funeral of every Hindoo increases the demand according to his station; the relatives of the deceased giving a brass cup to every Brahmin present at the ceremony; so that 5, 10, 50, 100, 1,000, and sometimes more than ten times this last number, are dispensed upon such occasions.*

HISTORICAL NOTICE OF TIN.

THE tin mines of Cornwall and Devon have been celebrated from remote antiquity. The Phœnicians are said to have been among the earliest visitors to our shores in search of this valuable metal, and that the horned or curved appearance of the coast, as viewed from the sea, suggested to them a name which the Romans translated into *Cornubia* and the Britons into *Cornwall.* Herodotus, who wrote about 450 years before our era, mentions the tin islands of Britain, under the general appellation of *Cassiterides,* from κασσίτερος, tin. The Greeks of Marseilles obtained tin from this source, and after them came the Romans, whose merchants had long endeavoured in vain to ascertain the tin market of their commercial rivals.

Some particulars respecting the tin-trade of Cornwall in the time of Augustus are given in a passage in the writings of Diodorus Siculus. He says:—"We will now give an account of the tin which is produced in Britain. The inhabitants of that extremity of Britain which is called Belerion both excel in hospitality, and also, by reason of their intercourse with foreign merchants, are civilized in their mode of life. These prepare the tin, working very skilfully the earth which produces it. The ground is rocky, but it has in it earthy veins, the produce of which is brought down and melted and purified. Then, when they have cast it into the form of cubes, they carry it to a certain island adjoining to Britain, and called Iktis. During the recess of the tide, the intervening space is left dry, and they carry over abundance of tin to this place in their carts. And it is something peculiar that happens to the islands in these parts lying between Europe and Britain; for at full tide, the intervening passage being overflowed, they appear islands, but when the sea retires, a large space is left dry and they are seen as peninsulas. From hence then the traders purchase the tin of the natives, and transport it to Gaul; and finally, travelling through Gaul on foot, in about thirty days they bring their burdens on horses to the mouth of the river Rhone."

---

* BELL's *Commerce of Bengal,* quoted by M'Culloch, to whose excellent Commercial Dictionary (new edition, 1849,) we are indebted for the above as well as some of the subsequent statistics.

The islands referred to in this description were long supposed to be the Scilly isles; but a recent anonymous writer, who appears to have bestowed considerable attention on the inquiry, says, "We do not believe tin was ever raised in the Scilly isles; they are situated so far from the Land's End, that in very clear weather, at an elevation of between two and three hundred feet, we have been scarcely able to make them out. The rocks, sunken and apparent, and the currents, make the navigation between them and the mainland at all times dangerous; and unless in summer, frail canoes of hides could not live upon it. As to their having been accessible to wagons at ebb tide, as Diodorus states, it is as much out of the question as that Ushant is accessible from Plymouth in the same way; the coast is a terrific one, iron-bound, as the sailors say; and, in times when navigation is so well understood as at present, it is very dangerous from the variations of tides and currents. We are of opinion that the present St. Michael's Mount is meant, which, at ebb-tide, is accessible from the mainland, where tin is found in two ways, in stream-works and in mines. The Scilly Isles are mere rocks. St. Michael's Mount, it is true, is no more of itself than a mere rock; but we know that there was other land, perhaps isolated also, in Mount's Bay, and since submerged. In those days we do not believe tin was found in mines, whence it is now taken in the state of ore: it was in all probability collected from the stream-works, as they are still called, in the form of what is denominated *grain tin.* These stream-works are horizontal excavations open to the earth's surface, whence the tin is obtained by washing. The tin is found in this way, as gold-dust is met with in some parts of the world; and indeed in Cornwall too; for in these very stream-works the workpeople collect a grain now and then, and keep it in a quill until it is full. These stream-works do not require machinery to descend into them or to drain them; pickaxes of holm, boxwood, and harts' horns have been found in them often—the instruments of a rude people and age. Skin canoes or coracles could never have reached Scilly over the most turbulent of seas. May not Æstrymon, in Avienus, mean the Lizard; the bays and isles, Mount's Bay?—then all is accounted for."

It has been already stated that the chief use of tin in these early times was for the purpose of making bronze. In the sixth and seventh centuries, the general use of bells in churches, then introduced into Western Europe, considerably increased the demand for Cornish tin, more particularly as bells of large size were cast for the principal cathedrals. The sale of tin was also subsequently greatly increased by the demand produced by the use of bronze cannon. In the thirteenth century the chief emporium of the tin trade was Bruges; and in the fourteenth century, the merchants of Italy obtained the tin of Cornwall, and distributed it among the countries of the Levant, though Bruges still continued to be the great market for Cornish tin.

In the reign of King John the property of the mines was precarious and unsettled, and the tin raised was engrossed by the Jews, to the great regret of the barons and their vassals, the right of working being wholly in the king as Earl of Cornwall. The tin-farm of Cornwall then amounted to only 100 marks (66*l.* 13*s.* 4*d.*) per annum, while the tin of Devon was at the same time farmed for 100*l.*

During the time of Richard Earl of Cornwall and King of the Romans, the produce of the tin mines seems to have been very considerable, so that he derived great revenue from them; but after the banishment of the Jews, in the 18th of Edward I., the mines were again neglected. "After this it hapned," says Carew, "that certain gentlemen, being lords of seven tithings in Blackmore, where grounds were best stored with this minerall (tin), grewe desirous to renew this benefit; and so, upon suit made to Edmond Earle of Cornwall, sonne to Richard King of the Romans, they obtayned from him a charter, with sundrie privileges; amongst which it was granted them to keepe a court and hold plea of all actions (life, lymme and land excepted); in consideration whereof, the sayd lords accorded to pay the earle a halfpeny for every pound of tynne which should be wrought; and that for better answering this tax the said tynne should bee brought to certayne places purposely appointed and there peized, coyned and kept, untill the earle's due were satisfied. Again; the lords of these tithings were for their parts authorized to manage all stannerie causes, and for that intent to hold parliaments at their discretion; and in regard of their labour, there were allotted unto them the toll-tynne within those tithings, which their successors do yet enjoy. This charter was to be kept in one of the church-steeples within those tithings; and the seale had a pickaxe and shovell in saultier graven thereon."

This and the charter of King John were confirmed in the 31st year of Edward I, and the tinners of Cornwall and Devon, who previously formed one body, were divided. Five coinage-towns for Cornwall and three for Devon were appointed; and each tinner was permitted to sell his own tin, unless the king insisted on buying it himself.

Other charters followed, and the warden of the stannaries was appointed, with the power to nominate a vice-warden. In the reign of Elizabeth the tinners of Cornwall were divided into four sections, named from the chief works at that period, *Foymoore,* *Blackmoore*, *Tiwarnaill* and *Penwith*. Each division had its steward, appointed by the lord warden, who kept his court once in three weeks. In these courts were tried cases of debt and trespass, in which any one dealing in black tin (the ore) or white tin was either plaintiff or defendant. The verdict was given by a jury of six tinners, according to which the steward pronounced judgment. According to Carew, the verdicts were not always fair. In matters of importance, in which the whole stannary was concerned, the lord warden or the vice-warden impanelled a jury of twenty-four principal tinners, six for each division, returnable by the mayors of the four stannary towns, Helston, Truro, Lostwithiel and Liskeard. The consent of sixteen of these twenty-four *stannators*, as they were called, was sufficient to enact any new law.

Carew has given a valuable record of the state of the Cornish mines two centuries and a half since. He first notices stream-works and lodes, and the opinion of the tinners that the tin-stones in the stanniferous gravels were derived from the lodes by the deluge. He next describes the process of tracing the lode, called *shoding*, or *shoading*, which seems to have been then conducted much in the same way as is now practised,—that is, by tracing fragments detached from the lode, following the slopes of hills, until by the increase in the abundance of such fragments they find the upper part of the lode itself, whence they have been derived. He remarks that the shode for the lodes "either lieth open upon the grasse, or but shallowly covered." Having found this shode, "they next," he says, "sank pits of five or six foote in length, two or three foote in breadth, and seven or eight in depth, to prove where they may so meet with the load (lode). If they miss the load in one place, they sincke a like shafte (pit) in another beyond that, commonly farther up towards the hill, and so a third and a fourth, until they light at last upon it." If the lode thus discovered seemed likely to be profitable, the discoverer would usually associate others with him in the working; and the company thus formed appointed a captain to superintend the work, and to attend to the mine and the pumps. "In most places," says our author, "their toyle is so extreame as they cannot endure it above four hours in a day, but are succeeded by spels; the residue of the time they weare out at coytes, kayles, or like idle exercises. Their kalendar also alloweth them more holy-dayes than are warranted by the church, our lawes, or their own profit." The tools were only a pickaxe and a shovel, and with these they would sometimes follow the lode to the depth of forty or fifty fathoms, the miners being let down and taken up in a stirrup by two men who wound the rope probably over a winch. But where the hang or inclination of the lode was considerable, the miners worked to a convenient depth, when they sunk a shaft from the top, "to admit a renewing vent, notwithstanding, their work is most by candlelight." The loose work was kept up by timber, and the rate of progress was but slow, for "a good workman shall hardly be able to hew three foote in the space of as many weeks." The water which drained into the mine was at this time a great hindrance, and often led to the abandonment of a valuable mine. The draining machinery was "composed of pumps and wheeles, driven by a streame, and interchangeably filling and emptying two buckets, and such like." In some places, where the works were on a hill side, canals were cut from the lode to the nearest valley, but these were "costly in charge and long in effecting."

In dressing the ore, it was first broken with hammers, and then conveyed to the stamping mills, consisting of three or six beams, shod at the bottom with iron. These being raised by means of cogs and a water-wheel, and falling by their own weight upon the ore beneath, crushed it. After this it was ground into a fine sand by a *crazing mill*, worked by a water-wheel, in which the ore was passed between two grinding-stones. The next process, the washing of the ore, is curious. "The streame, after it hath forsaken the mill, is made to fall by certayne degrees, (steps) one somewhat distant from another; upon each of which at every descent lyeth a green turfe, three or four foote square, and one foote thick. On this the tinner layeth a certayne portion of the sandie tinne, and with his shovell softly tosseth the same to and fro, that through this stirring, the water which runneth over it may wash away the light earth from the tinne, which, of a heavier substance, lyeth fast on the turfe. Having so cleansed one portion, he setteth the same aside, and beginneth with another until his labour take end with his taske. * * * * * After it is thus washed, they put the remnant into a wooden dish, broad, flat and round, being about two foot over, and having two handles fastened at the sides, by which they softly shogge the same to and fro in the water between their legges, as they sit over it, until whatsoever of the earthy substance that was left be flitted away. Some of later time, with a sleighter invention and lighter labour, doe cause certaine boys to stir it up and downe with their feete, which worketh the same effect; the residue, after this often cleansing, they call black tynne, which is proportionably divided to everie of the adventurers, when the lord's part hath been first deducted upon the whole."

Much of the tin was lost by this process, and our author states that Sir Francis Godolphin, with the aid of "a Dutch myncrallman," was enabled to make tin with great profit from the refuse of the above process. After the black tin was divided, each man took his own share to the blowing house, where it was melted with charcoal, the fire being blown by bellows (whence the name of the *blowing house*) worked by a water-wheel. This process was so roughly conducted that "divers light sparkles" of tin were commonly driven up on the thatched roof in such quantities that it was usual for the owners of these blowing houses to burn them once in seven or eight years, and they found as much tin in the ashes as paid for a new building, "with a gaine-full over-plus."

It appears from a speech of Sir Walter Raleigh in parliament in 1601, when lord warden of the stannaries, that the pay of a working tinner was then 4*s.* per week, finding himself. This was a great change for the better, because, as he remarks, previous to the patent granted to him by Queen Elizabeth, of the pre-emption of Cornish tin, the tinner received only 2*s.* a-week, finding himself. Carew also notices the bad condition of the tinners at this time, and observes that the parishes in which tin was worked were in a "meaner plight of wealth" than in those which were simply agricultural. The London merchants had agents in Cornwall, who advanced money and wares to the needy tinners, upon agreement that they should furnish certain quantities of tin at the next coinage, by which the tinners experienced great loss. Much of the tin raised at this period seems to have been in the hands of the London merchants.

These details refer chiefly to stream works. The method of undertaking a tin mine at this period is well explained by Carew:—"Their workes, both in *Streame* and *Load,* lie either in Severall, or in Wastrell, that is, in enclosed grounds or in commons. In *Severall* no man can search for tynne without leave first obtained from the lord of the soile; who, when any myne is found, may work it wholly himself, or associate partners, or set it out at a farme certaine, or leave it unwrought, at his pleasure. In *Wastrell* it is lawful for any man to make triall of his fortune that way, provided that hee acknowledge the lorde's right by sharing out unto him a certain part which they call toll; a custome savouring more of indifference than the tynners constitutions in *Devon,* which inable them to digge for tynne in any man's ground, inclosed or unclosed, without license, tribute, or satisfaction. Wherethrough it appeareth that the law makers rather respected their owne benefit than equitie, the true touch of all lawes. The *Wastrel* workes are reckoned among chattels, and may pass by word or will. When a myne is found in any such place, the first discoverer aymeth how farre it is likely to extend, and then in the foure corners of his limited proportion diggeth up three turfes, and the like (if he list) on the sides, which they term *bounding*, and within that compass every other man is restrained from searching. These bounds he is bound to renew once everie yeare, as also in most places to bestow some time in working the myne, otherwise hee loseth this privilege. The work thus found and bounded, looke how many men doe labour therein, so many *doales* or shares they make thereof, and proportionably divide the gaine and charges. The lord of the soyle is most-where allowed libertie to place one workman in every fifteene for himself, at like hand with the adventurer, if hee be so disposed."

In the reign of Charles I. the charters which had been granted in the reign of Edward III., by which the tinners of Cornwall obtained liberties distinct from those of Devonshire, were revised, confirmed, and the jurisdiction of the stannaries restrained. In this reign the ancient records of the stannaries, kept at Lostwithiel, were burnt by the parliamentary army.

It appears that formerly Devonshire was a more important tin country than Cornwall. According to Bishop Gibson's version of Camden, "Though Cornwall has now the greatest share in these mines, there being little or no tin made in Devonshire, yet in King John's time there was more found in that county than in Cornwall; for it appears that the coinage of Devonshire was then set to farm for 100*l.* per annum; whereas that of Cornwall yielded but 100 marks. And, according to this proportion, the tenth thereof (6*l.* 13*s.* 4*d.*) is at this day paid by the Crown to the Bishop of Exeter. But King John did not first bestow these tenths upon the church, as some say, for he only restored them upon a complaint made by the bishop that those who rented the stannaries refused to pay him his due."

The stannary laws continued during many reigns, with little or no alteration, to settle disputes among the miners in all cases except those affecting land, life, or limb. The last stannary parliament was held at Truro, in 1752, and continued, by adjournments, to September, 1753. The stannary prison was at Lostwithiel; but by an act passed in the reign of William IV. it was transferred to Bodmin. This act was "For the better and more expeditious administration of Justice in the Stannaries of Cornwall, and for enlarging the jurisdiction and improving the practice and proceedings in the Courts of the Stannaries." By this act the equitable jurisdiction of the vice-warden is extended to all matters connected with the working of lead, copper, or other metal or metallic minerals within the county of Cornwall. By an act passed in the first year of her Majesty's reign, the duties payable on the coinage of tin in Devon and Cornwall were abolished, and a compensation in lieu of them was given to the duchy, founded on the amount of the clear annual revenue derived from them for the last ten years, and at the same time the duties on the import of foreign tin were reduced, and fixed at 15*s.* per cwt. for tin, and 10*s.* per cwt. for tin ore.

From the year 1720 to 1740, the annual produce of the Cornish tin mines was about 2,100 tons. The produce went on increasing till it amounted in the ten years from 1790 to 1800 to 3,254 tons a-year. During the next fifteen years the produce fell off: and for the five years ending with 1815 it was much under 3,000 tons a-year. But in the last-mentioned year a great increase took place, and since 1816 the produce has been, with the exception of 1820, always above 3,000 tons. In 1843, the average produce of the mines was estimated at above 5,000 tons a-year.

HISTORICAL NOTICE OF LEAD.

Lead is mentioned frequently in our version of the Bible; and there is not much doubt that the terms which our translators understood to mean lead, apply to that metal. But it has been supposed by Beckmann, and others, that, in those passages where *tin* is mentioned, lead of some kind is meant. The Hebrew word *bedil* has been translated *tin;* which term the Greek translators of the sacred books rendered *cassiteros;* and this last word has been translated by more modern writers by *stannum.*

" In the Book of Numbers, (xxxi. 22,) Moses seems to name all the metals then known; and, besides gold, silver, brass (properly copper), iron, and lead, he mentions also *bedil,* which all commentators and dictionaries make to be tin. When Ezekiel (xxvii. 12), gives an account of the commerce of Tyre, he names among the commodities, silver, iron, copper, and *bedil.* In Zechariah iv. 10, the plummet of the builder, or architect, is said to be made of the *bedil* stone.* In Isaiah i. 25, the word occurs in the plural number, and appears there to denote either scoriæ, or all those inferior metallic substances which must be separated from the noble metals. In the old Greek versions of these Hebrew books, *bedil* is always translated by *cassiteros,* except in the passage of Isaiah, where no metal is mentioned. In Zechariah, the translator calls the *bedil* stone, *τὸν λίθον κασσιτέριον* (the tin stone). There can hardly be a doubt that, for the purpose here mentioned, people would employ, not the lighter metal tin, but lead, and that the plummet was called the lead-stone,

---

* In the English version, " The plummet in the hand of Zerubbabel" is all that is mentioned; but in Luther's translation, which our author evidently refers to, as well to the original Hebrew, it runs thus: " Das zinnerne Mass in Serubabels Hand."

Digitized by Google

because at first a stone was used." Beckmann thinks it probable that, in the first quoted passage, *bedil* is our tin. "But must it not appear astonishing," he asks, "that the Midianites, in the time of Moses, should have possessed this metal? Is it not possible that the Hebrew word denoted a metallic mixture, or artificial metal, which formerly was an article of commerce, as our brass is at present?"

Beckmann considers that the *stannum* of the ancients was no peculiar metal, or, at any rate, not our tin, but a mixture of two other metals, which, like our brass, was made into various articles, and employed for different purposes; on which account an extensive trade was carried on in it. It appears, from a passage in Pliny, that the same furnace yielded from the same ore stannum, argentum, galena, and nigrum plumbum. Now, as tin ores rarely, if ever, contain silver, while there are few lead ores but what are impregnated with it, and many of them so largely that they may be called silver ores, it seems likely that Pliny referred to some kind of lead ore.

"It may appear singular," observes Beckmann, "that the ancients should have had *nigrum plumbum*, undoubtedly our lead, in such abundance, that Pliny was able to make of it a particular division. But, in ancient times, little attention was paid to a small admixture of silver; they were accustomed to separate the precious metal, in general, only when it was capable, by the old imperfect process of smelting, of defraying the expenses; which certainly would not be the case, when a quintal of ore contained only a few ounces, or even a pound of silver. Strabo says this expressly of some Spanish ores. Such poor ores were then used merely for lead; and hence it has been supposed that our silver refiners might separate silver with advantage from the lead of the ancients.

In addition, therefore, to the pure lead which flowed from the ore on its first fusion, the ancients obtained, as we do, a considerable quantity of lead from argentiferous ores, from which they separated the silver, and revived the lead. The ore was first stamped, then washed and roasted, and formed into a paste; this was then put into the furnace, and by the first fusion gave a regulus* of silver and lead, which was called *stannum*, and was a substance similar to that known to the German metallurgists by the name of *werk*. The produce obtained by the second fusion was the *argentum* silver, called in German *treiben*; and besides that, the half vitrified lead called *galena* by Pliny; and also *molybdæna;* which substance being once more fused, or revived, again yielded lead. In this manner were obtained three different productions, which were all used in commerce, namely *stannum*, *argentum*, and *galena*, or revived lead, *plumbum nigrum*. These Pliny seems to have considered as component parts of lead ore; but not, indeed, according to the present signification. "In my opinion, the oldest *cassiteron* of the Greeks was nothing else than the *stannum* of the Romans, the *werk* of our smelting-houses; that is, a mixture of lead, silver, and some other accidental metals. That this has not been expressly remarked by any Greek writer, is, to me, not at all surprising. We should not have known what *stannum* was, had not the only passage of Pliny which informs us been preserved."†

The result of this inquiry leaves us still uncertain as to the exact nature of the metal called *bedil* by the Hebrews, *cassiteron* by the Greeks, and *stannum* by the Romans. There can, however, be no doubt that lead, properly so called, was used extensively by the people of antiquity. Camden, on the authority of Pliny, says, "In Britain, in the very upper crust of the ground, lead is dug up in such plenty, that a law was made on purpose to stint them to a set quantity." To what extent the lead ore was worked by the Britons themselves, or by the people who visited them for the purposes of trade, cannot now be ascertained; but there is no doubt that, under the government of the Romans, the lead of this country was a very important article of commerce. Blocks or pigs of lead have been discovered, having Latin inscriptions;* and in the neighbourhood of the mines are to be traced the remains of Roman stations, houses, and burial places. The Saxons, who succeeded the Romans in Britain, did not neglect the mineral treasures so abundant in the centre of their acquisitions. An important mine, near Castleton, was called by them "Odin," after the name of one of their divinities. The mines in the neighbourhood of Wirksworth were wrought before the year 714; at which period that district belonged to the nunnery at Repton, over which Eadburga, the daughter of Adulph, king of the East Angles, presided as abbess. In that year, the abbess sent to Croyland, in Lincolnshire, for the interment of St. Guthlac, who was originally a monk of Repton, a sarcophagus of lead, lined with linen. This lead was obtained from the possessions of the old Saxon religious establishment at Repton, part of which were the mines near Wirksworth. In the year 835, Kenewara, then abbess of the same nunnery, made a grant to Humbert, the alderman, in which she surrenders that estate of mines, called *Wirceworth*, on condition that he gives, annually, as a rent to Archbishop Ceolnoth, lead to the value of three hundred shillings, for the use of Christ's Church, Canterbury. On the destruction of the religious houses by the

---

* A term introduced by the alchemists. It means, literally, a *little king*, and refers to the metallic state as one of royalty, compared with the native earthy condition. The term is now nearly obsolete.

† BECKMANN'S *History of Inventions*. A cheap translation of this work, with additional notes, by Dr. Francis and Professor Griffith, was published in 1846, in two volumes.

---

* They are described in the Archæologia, vols. v. vii. and ix.

Danes, in 874, it is probable the lead mines became the property of the crown. The mines in the Peak and in the wapentake of Wirksworth, were regarded, at an early period, as the peculiar domain of the sovereign, and, as such, are mentioned in Doomsday-book.

The lead mines of Derbyshire occur in the hilly country in the neighbourhood of the Peak, and are designated in the records of the Duchy of Lancaster as *the King's field:* this includes the whole wapentake of Wirksworth, as well as part of the High Peak; and comprises the greater part of the mountain limestone district of Derbyshire. The mines are regulated by ancient laws, the origin of which is unknown; but it appears, from historical records, that Edward I. directed the sheriff of the county to call a meeting at Ashbourn, of such persons as were best acquainted with the rights and customs of the mines. On this occasion, the miners petitioned that their privileges should be confirmed under the Great Seal, as an act of charity to preserve them from the danger to which they were exposed. In the reigns of Edward VI. and Queen Mary, several alterations were made in the mineral laws; and within the last twenty years, various new regulations have been approved and passed into laws at the great Barmote courts of the High Peak and wapentake of Wirksworth.

By these ancient laws and privileges, all persons had the power to dig and search for veins of ore without being accountable to the owners of the soil for any damage done to the surface, or even to growing crops. It is now held that, unless a miner procures ore enough from any vein he may be in search of to *free* the same—that is, to pay to the king, or to his farmer or lessee, a dish of ore, he is liable to the occupier for any damage committed in the search.

In the King's Field, a mineral court is held, under the presidency of a *bar-master*, who, assisted by a jury of twenty-four miners, decides all questions respecting the duties or *cope*, payable to the king, or his lessee. They also regulate the working of the mines by those to whom the bar-master has given possession; and, in certain cases, enforce the payment of debts incurred in working them.

These laws, as Mr. Farey* remarks, evidently originated in the very infancy of mining, and were adapted to the working of the mines entirely by manual labour. A person having found a vein of ore, made certain crosses on the ground, or a mark of temporary possession, and then informed the bar-master, who attended and received a dish of ore, the first produce of the mine, as the condition of permitting him to proceed in working his *meer*, or measure of twenty-nine yards in length, of the vein. At the same time, the bar-master took possession of the next adjoining fourteen and a half yards, or half-meer, of the vein for the king. If the vein seemed promising, it often happened that other persons applied to be admitted, each to free his meer, or twenty-nine yards in length of the rake vein, in succession. It was a condition, that each person, or company, possessing their meer, or meers, in partnership, called *groove-fellows*, should immediately begin and continue to work at their mine; and in case of intermission for three successive weeks, the bar-master was authorized to dispossess them, and give the mine to another.

The first meers, or mines, of this kind were in districts where the limestone has no other cover than the soil. The miners worked with mattocks, or picks, and with hammers and iron wedges in the harder veins, removing the ore, and throwing out the spar and rubbish on each side of the vein. Having worked the vein to a certain depth, they erected a square frame, composed of four narrow planks of wood, placed across, and pinned at the corners: on this frame two upright posts were erected, with holes or notches, to receive the spindle of a windlass, for winding up the ore in small tubs. This apparatus, called a *stowse,* being erected on each meer, the working was continued to the depth of many yards; the heaps of rubbish meanwhile accumulating on each side many hundred yards in length, with other similar ditches and heaps from other meers, crossing them in various directions. When the miners in this way had excavated as low down as their simple means permitted, or when the ore ceased to be profitable, the meer was abandoned; but as, in after times, other adventurers might appear and carry on the work, the poor farmer of the land thus disturbed was forbidden by the strictest laws from returning the barren rubbish into the deep and dangerous ditches thus excavated. At the time when Mr. Farcy wrote, (1811,) numbers of these ditches remained in the state in which they had been left by the miners, altered only by the treading of cattle, and the natural mouldering of the sides. In some cases, however, a better system was adopted; in rich mines, instead of throwing all the rubbish to the surface, it was thrown upon floors, or stages of wood, called *bunnings,* placed across the whole length of the mine, except just under the stowses, at which places they sunk six or eight feet lower; and after clearing some distance, erected other bunnings under the former, on which the refuse was thrown as before. As the work proceeded, the shaft under the stowse was lined with timber, or stone; and the vein-stuff being thrown on the bunnings around it, a regular hill was at length formed, called the *hillock,* or the *mine-hillock.*

---

* Survey of the Agricultural and Mineral Districts of Derbyshire.

In process of time, the laws which required a working stowse to be used at least once in three weeks, for drawing ore at each meer, became relaxed so far as to allow models of stowses, or small sham drawing apparatus, made of thin laths of wood, which

Digitized by Google

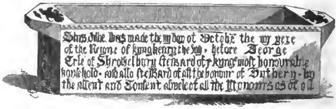
the bar-master provided, to be used as the means of keeping possession of all the meers but one on a consolidated mine; a custom which still prevails, and is so rigidly enforced, that a mine on which large steam engines may have been long used, is not held to be legally occupied, unless one of these pigmy memorials of the primitive mode of drawing ore is constantly kept "in sight of all men," as the law expresses it, and others on each of the meers of ground or lengths of twenty-nine yards of which the mine consists. Persons detected removing or destroying the bar-master's stowses, though placed across the middle of a cultivated field, a common, or on the fence wall next a public road, are subject to certain penalties. These models, to be effective, must have no nails in their structure, but be pinned together with wood, as was the case with the original machines. If a known unoccupied vein crosses a paddock, a garden, or a gentleman's park within the King's Field, it must be leased of the bar-master by the payment of a dish of ore, and the erection of these sham stowses, and even a real stowse, which must be worked periodically in however slight a manner. If this be omitted, any person, on application to the bar-master, may take possession of such vein, and destroy the land without mercy. Such barbarous laws evidently interfere with the culture of the land, especially when it is considered that there are thousands of veins of ore which are too narrow or too poor to be worked with profit; and yet, to prevent needy adventurers from claiming them, it was necessary to keep the land *stowsed* even on the barren hills of grit-stone rocks and the coal-measures.

All lead ore which is dressed ready for sale in the King's Field, is required to be measured in the presence of the bar-master before it is removed from the mine; for which purpose a rectangular box is used in the Low Peak, twenty-eight inches long, six wide, and four deep, called a *dish*, and reputed to hold fourteen Winchester pints when level full;* in the High Peak, sixteen pints are reckoned to the dish. In measuring the ore, every twenty-fifth dish is set aside by the bar-master as the King's lot, cope, or duty.

One of the earliest notices of the smelting of lead in our own country is given in the Philosophical Transactions of the Royal Society for 1668. It is written by Mr. Glanvil, and refers to the Mendip Hills in Somersetshire. "The ore," he says, "lies in veins as a wall; the clearest and heaviest is the best, of which 36 cwt. may yield a ton of lead. The workmen beat the oar with a flat iron, then cleanse it in water from the dirt, and sift it through a wire sieve. The ore tends to the bottom, and the refuse lies at top; and these are the preparations they make use of before it is fit for fusion. For this purpose they have a hearth about five feet deep, set upon timber, to be turned as a windmill, to avoid the inconvenience of smoke upon a shifting wind. The hearth contains half a bushel of ore and charcoal, with bellows on the top, worked by men treading on

---

* The following is a representation of the old brazen dish for measuring ore in the Low Peak.



It has the following inscription :—

"This Dishe was made the iiij day of October, the iiij yere of the Reigne of Kyng Henry the VIII. before George Erle of Shrowesbury, Steward of the Kyng's most honourable household, and also Steward of all the honour of Tutbery, by the assent and Consent as wele of all the Mynours as of all the Brenners within and adioynyng the lordshyp of Wyrkysworth percell of the said honour. This Dishe to Remayne In the Moote-hall at Wyrkysworth hangyng by a Cheyne, So as the Merchantes or mynours may have resorte to the same at all tymes to make the trew mesure after the same."

Digitized by Google

them. The charcoal is put upon the hearth where the ore is, laying dry sticks of oak upon the top, which they call their white coals. There is a sink on the side of the hearth, into which the lead runs, that holds about a hundred and a half. Then it is cast into sand, forming what are called *sowes.* They have a bar to stir the fire, a shovel to throw it up, and a ladel heated red-hot to cast out the melted metal. Once melting is enough; and the best, which is heaviest, melts first."

In addition to those of Derbyshire, the most productive English lead mines are situated in Allendale, and other western parts of Northumberland; at Alstone Moor, &c., in Cumberland; in the western parts of Durham; in Swaledale, Arkendale, and other parts of Yorkshire; there are also mines in Salop and in Cornwall. The Welsh mines are principally situated in the counties of Flint, Cardigan, and Montgomery; those of Scotland, in Ayr, Kirkcudbright, and Lanark; and those of Ireland, in Wicklow, Waterford, and Down. There are also valuable lead mines in the Isle of Man.

The quantities of lead ore and lead produced in the United Kingdom in 1847 are as follows:—

	Lead Ore.		*Lead.*
England	59,614½	„	39,507½
Wales	18,147½	„	12,294
Ireland	2,251	„	1,380
Scotland	1,159	„	822½
Isle of Man . . .	2,575	„	1,699
	83,747		55,703

In 1848 the price of lead was about 16*l.* per ton. A considerable quantity of silver is now obtained from lead. It is supposed that out of 55,000 tons of lead raised in Great Britain, about 25,000 yield 8oz. per ton of silver, or 200,000 ounces of silver, which, at 5*s.* per ounce, will be 50,000*l.* a-year.

MINING.

The mineral produce of the earth may exist in regular strata, and alternate with beds of rock of great extent, as in the strata of coal and iron ore of South Wales and Staffordshire, and the coal in the Newcastle and Durham districts; or it may occupy cracks or fissures which have evidently been produced in the rocks subsequently to their deposition. These cracks may be formed in stratified or in igneous rocks, and the mineral substance which fills them differs more or less from the rocks themselves, and is commonly known by the term *vein*, or *lode*. This term, however, is usually restricted to metallic ores; for when the cracks are filled up with matter not metallic, but evidently injected in a state of fusion, the word *dyke* is employed to distinguish it. Non-metalliferous veins, usually accompanying veins of ore, and at right angles thereto, are also called *cross courses*. The metalliferous veins are commonly filled with copper, lead, tin, and other metals, not in the pure or native state, but in the state of *ore*,—that is, combined with sulphur, oxygen, carbonic acid, and also associated with salts of lime, baryta, quartz, and argillaceous matter. By far the larger number of veins are dykes or cross courses, containing no metallic ore, or not enough to make them worth working.

The object of mining is to pursue one or more of these metalliferous veins through all the rocks met with in its downward descent, and raise the ore to the surface. The most important veins continue to descend beyond the reach of the deepest mine, unless intersected or displaced by a vein of newer origin, producing *faults* and disturbances somewhat similar to those noticed in seams of coal.

Veins which have been traced to their termination are generally small and unimportant, and when lost sight of, it is usually by passing into narrow cracks. The breadth of a vein is very irregular; it may be three or four feet across, or only an inch or two, and in the course of a few fathoms swell out into a breadth of eight or ten feet. The different appearances of veins have various local or technical names assigned to them. Where the vein is divided into portions, inclined at different angles in different veins, but nearly parallel in the same vein, the terms *pipe* and *shoot* are applied. The term *shoot* is also applied in certain districts to masses of ore in stratified rocks which take an oblique direction in the veins, and become conformable to the dip of the beds. When the direction of the vein itself is nearly parallel with that of the beds, and the ore makes no such shoots in a lode, it is called a *pipe vein*. Where veins expand against layers of rock, and form lateral extensions, these are termed *flats*. Small veins passing off from the ore to the rocks, are called *strings*, and when very small, *threads*, and these often become rich when the vein itself is poor.

Veins usually occur in a nearly vertical position, differing therefrom in the north of England seldom more than ten degrees, but in Cornwall more than this, sometimes as much as forty-five degrees. The dip or inclination of the vein to the horizon is called its *underlie*, *hade*, or *slope*, and the intersection of the vein with the surface is the *strike*, and determines what is called the *direction* of the vein. In Cornwall the productive veins almost always run east and west, and the cross courses north and south. In the English lead districts the direction of the productive veins is almost always east and west, and they are traversed by cross courses, which are not productive, at right angles to them. The walls or portions of rock which enclose the vein are called the *roof* and the *floor*, one of course being the upper, and the other the lower wall. The rock in contact with the vein is usually softer than in other places, probably in consequence of the porosity of the vein allowing water to filter through it.

The mineral contents of a vein have also been divided into the *veinstone* and the *ore*, the former consisting of silex, or fluor spar, or carbonate of lime, all in a crystalline state. These minerals are important to the miner only as they enable him to judge as to the abundance or absence of the ore. The ore usually occurs in small veins within the principal vein, or in grains, or crystalline masses, and disseminated crystals. Where the veinstone is earthy or powdery, there is generally much ore, while sterile veins are commonly filled with sandstone or clay, or with broken fragments of adjoining rocks.

A vein does not always become richer as its depth increases; but it generally happens that where the rock changes in hardness and texture, or to one of a different character, there is an alteration in the value of the lodes. Thus it has been observed in Cornwall, that a vein producing copper ore in slaty ground may enter granite without any break or change of direction, and become at first richer, and furnish ores of a different mineral character, but if traced far into the granite, it generally becomes poor; but when a productive vein crosses an *elvan* or granite dyke, the ore in some cases becomes rich and abundant, and in others disappears altogether.

These remarks respecting mineral veins may be summed up by the following general conclusions:— 1. That mineral veins are of various ages, and quite independent of the age of the rock in which they occur. 2. That the fissures which now form mineral veins have not been filled up without some reference to the nature of the rocks in which they are contained, and that the filling up was therefore most probably subsequent to the formation of the fissure. 3. That the fissures which contain metallic ore are chiefly in certain definite directions, constant in the same locality in most cases, but that these are crossed nearly at right angles by another set, which are unproductive.

It has been already remarked, that veins or lodes are as perfect at the surface of the mountain as at great depths, and may be traced by removing the soil which covers the rock. Many lodes have been accidentally discovered in this way during the formation of roads and other operations requiring the removal of the surface soil. One of the ancient privileges of the tin miners of Cornwall empowered them to open the grounds of other persons to search for a lode; but there are usually indications of its presence at a considerable distance from its outcrop; such as springs of water impregnated with metal, or detached fragments of ore. By tracing these fragments until they increase greatly in number, the upper part of the lode is found. These fragments are called *shoads*, and the method of tracing out the vein by their means is called *shoding* or *shoading*.

The beds of mountain streams in many mining districts are sufficiently rich to become the scene of operations distinct from mining. By collecting the sand and gravel of these streams, and throwing it upon an inclined plane upon which a fall of water is conducted, the lighter stones and earth are washed away, and the ore remains behind. These *stream works*, as they are called, are in our own country confined to the ores of tin, and to a few poor mines; but in many parts of the world very large supplies of gold, silver, and platinum are obtained in this way, by sifting and washing sand in which small grains of the precious metals are disseminated. In the island of Banka, in the Eastern Archipelago, as much as 3,500 tons of tin have been annually exported, and this large quantity has been obtained entirely from stream works.

But in a country where mining operations are conducted with skill and vigour, this method would soon be found inadequate to supply the demand for a common and useful metal, such as tin; the gravel would gradually be traced along the bed of the stream to the outcrop of the vein, which would then be put in requisition to increase the supply. But in the absence of metalliferous gravels which can be thus traced up the course of a stream, and where the existence of veins is only probable, a method, called in Cornwall *costeaning*, is adopted to discover a vein. A pit is sunk through the soil to a small depth in the rock. If the miners find no ore, they *drive* or cut a gallery from the pit a short distance at right angles to the direction of the lodes found in the neighbourhood. In this way they may cut the lode they are in search of; but if still unsuccessful, they move further on in the direction of the gallery, sink another pit, and drive another gallery, until they have either discovered the lode or are forced to abandon the search in this spot.*

But supposing the position and direction of the mineral vein to have been ascertained, and some idea formed of its extent and value, a perpendicular pit or shaft is sunk to the depth of about sixty feet, when the men begin to work in a horizontal direction, and cut or drive a horizontal gallery or level into the lode. This is usually done by two sets of miners working in opposite directions, the ore and rubbish being raised in the first instance by a common windlass. As soon as the two sets of miners have driven the level about a hundred yards, they find it impossible to proceed for want of air; this being anticipated, two other sets of men have in the meantime been engaged in sinking from the surface two other perpendicular shafts to meet them, and from which the ore and materials may also be raised. In this way, by sinking perpendicular shafts a hundred yards from each other, the first level or gallery may be carried to any extent. While this horizontal work is going on, the first shaft, called the *engine shaft,* is sunk deeper; and at a second depth of sixty feet a second horizontal gallery, or level, is driven in the same direction as the first, and the perpendicular shafts are all sunk down to meet it. In this way galleries are formed at different depths so long as the lode continues to be profitable within certain depths. The engine-shaft is meanwhile continued to a greater depth than the lowest level, for the purpose of keeping the working shafts free from water, which rises in the mine from springs, or drains into it from the surrounding strata. Each successive level is also separately drained, that as little water as possible may descend to the lower workings. The object of these perpendicular shafts is not so much to get at the ores as to put the lode in a state capable of being worked by a number of men. It is evident that the shafts and galleries divide the rock into solid right-angled masses, each 300 feet in length, and 60 in depth. These masses are again subdivided

---

* "At an early period divining-rods and other superstitious means were resorted to by the miners when searching for mines, and even in later periods certain atmospheric phenomena have been denominated *burning drakes* by the vulgar; and their apparent fall to the earth was thought to point out the situation of rich and undiscovered veins of ore: by which class of persons whistling in a mine was supposed to frighten away the ore or lessen its chance of continuance; and hence they say arose the custom, that however miners may sing or halloo when at their work, no boy or man is to whistle under pain of severe chastisement from his fellow-miners."—FAREY.

Digitized by Google

by small perpendicular shafts into three parts; and by this arrangement the rock is finally divided into masses called *pitches*, each 60 feet in height and about 100 feet in length.*

The sinking of the preparatory shaft is a slow and tedious operation; but where the mine is already at work, and many galleries are already formed, the shaft is sunk in several pieces; that is, the sinking is commenced at the same time in several different levels, and much skill is required so to lay out the work that the different portions of the shaft may fit exactly when connected together, as a very small error of measurement in any of these dark subterranean passages would be sufficient to throw the whole into confusion. So also to drive an adit from one point to another through many fathoms of country requires great skill, particularly where, to save time, the work is commenced at both extremities. Much attention is also required that the water pumped up from these channels may not find its way back again among the workings. Some idea may be formed of the extent of drainage required in extensive mines from the fact, that the various branches of the principal level in Cornwall, called the "Great Adit," through which the waters of the numerous mines in Gwennap and near Redruth are discharged, measures about 2,600 fathoms, or nearly thirty miles in length, including the various branches. The greatest length to which any branch appears to have been extended from the adit mouth is at Cardrew Mine, and measures about five and a half miles. The highest ground it has penetrated is at Wheal Hope, where the adit is seventy fathoms deep. This adit is thirty-nine feet above the level of the sea at high-water in Restronget Creek, into which the waters discharged from it flow, its mouth being near Nangiles, in a valley communicating with the creek.

---

* Pits, open to the surface, are called *shafts;* in Cornwall, those which are not open to the surface, but are sunk from one gallery to another, are called *winzes.* Horizontal galleries in metalliferous veins are called *levels*, and those not in metalliferous veins *cross-cuts.* The principal gallery, or tunnel, by which the mine is drained, is termed the *adit*, or *adit-level.* The making of horizontal excavations is termed *driving;* those downwards are called *sinkings*, and those upwards *risings.*

It is obviously a point of importance that the principal shaft of a mine shall communicate directly with as many of the lodes as possible, when, as is usually the case, several veins occur in the same direction and at no great distance from one another. In the Fowey Consols mine in Cornwall, visited by the writer, thirteen lodes are worked, and are so near that one shaft (the Union) cuts through five of the lodes, and by means of a cross-cut at the sixty fathom level, communicates with all the rest. The workings on different lodes are connected by cross-cuts, so that the ores may be brought to the shaft, not only in the course of the lodes, but also at right angles to their courses.

The work underground depends chiefly upon the magnitude of the vein and the value of the ore. The general method of dividing the work into sections has been already noticed (page 37). When the lode is only a few feet wide, one gallery is sufficient, and, as it is only necessary to leave a passage to extract the ore, the levels at those places where the ore is narrow or *nipped in*, are also narrow and confined. Where the vein is poor, it may be a question whether to take that portion out at all. Where the lode is broader, the open spaces are larger. These are matters, however, which the captains of the mine decide. It is usual, in large mines, not to take out all the ore which can be immediately got at, but to leave it here and there to be worked as the general prospects of the mine may require, and to which the miners return if less ore is raised than could be wished. The ores thus kept in reserve are called the *eyes* of the mine, and in some mines are very valuable. When it is necessary in abandoning the mine, or from other circumstances, to remove them, it is called "picking out the eyes of the mine."

When it is required to extract very large masses of ore, and where the horizontal section is too large to be at once excavated, pillars are left to support the roof, and cross galleries are driven intersecting one another as in working coal. To avoid loss as much as possible where the galleries are lofty, the roof is supported by timbering. The veins of copper and tin in Cornwall are not generally sufficiently thick to require much artificial aid in extracting the ore, but timbering is necessary to avoid the danger that might arise from the sinking in of the upper wall of the vein. The timber used in the mines of Cornwall and Devonshire is Norwegian pine; and so great is the quantity in actual use, that it has been calculated that it would require 140 square miles of Norwegian forest to afford a supply for these mines. The timber required for this purpose is admitted free of duty.

As there are no noxious or inflammable gases generated in these mines, the ventilation is carried on simply by communication from shaft to shaft by the different levels or galleries. When these communications are properly made, currents set in different directions, varying according to the temperature at the surface and the increasing temperature at different depths.*

---

* The temperature of deep mines increases with the depth, and at sixty fathoms it is about 60°. This temperature is the same in winter as in summer, and therefore is independent of atmospheric changes. At 132 fathoms it is said to be 70°, and at 240 fathoms 80°. The increase becomes more rapid at greater depths, and greatly increases the difficulties of mining.

The ore is extracted from its stony matrix by the expansive force of gunpowder, of which 300 tons weight are used annually in Cornwall alone. A cylindrical hole being bored in the rock, a charge of powder is introduced and fired by a train or fuse. This method was long the source of repeated accidents, which are now happily precluded by the use of the safety-fuse, which consists of a cylinder of gunpowder enclosed within a hempen cord, which is first twisted and afterwards overlaid with another cord to strengthen the casing thus formed; then varnished to preserve the contents from injury by moisture, and finally covered with whitening to prevent the varnish from adhering. This fuse burns slowly, at the rate of eighteen inches per minute. By its means the charge may readily be lodged at any required depth in the rock, and any number of shots be fired at once.

When the ore has been detached, it is transported to the bottom of the shaft in wagons or *corves*,[*]

---

[*] From the German *korb*, a basket.

moving upon tramroads along the underground galleries. Extensive mines are furnished with miles of this subterranean railroad. The ores are lifted by machinery from the bottom of the shaft to the surface by a whim worked by steam-power, about half a ton or more being raised at once.

The terms upon which the miners are engaged in Cornwall are in many respects curious. The practical direction of the works is confided to agents named *captains*, who are generally selected from the most intelligent workmen. In the larger mines their duties are divided. A captain of the greatest experience usually governs the rest, and in conjunction with, and under the advice of, one of the partners or the principal manager, attends to all the business of the concern; while the departments of account, of the construction and care of engines, of the purchase of the various articles used, of the ore-dressing, &c., are superintended by persons appointed by the manager and principal captain. The captains under the chief have different duties assigned them: those employed underground see that the work is there conducted properly; while the *grass-captains* superintend the work on the surface, such as the dressing of ore, &c., which is done in the *bal* or upper part of the mine. Engineers are also appointed, and to them is confided the care of the various engines and machinery.

The persons working under the captains are divided into tributers, tutworkmen, and labourers. Tributers are men who agree to work a portion of a lode for a given time in the best manner they can, receiving as remuneration a certain portion of the value of the ores raised, as may be agreed upon. This portion necessarily varies according to the value of the part of the lode which is likely to be worked in the given time, usually one or two months. Thus, if the lode be rich, and is likely to continue so, a smaller portion of the value of the total quantity of the ores raised by the miners, taking the *pitch* or lode to be worked in the given time, is agreed upon, than when the lode is somewhat poor and may continue so. The mode in which the agreement is made is as follows:—Upon the *setting-days*, as these agreement-days are termed, the miners assemble before the counting-houses, and meet the captains, who have previously examined the various parts of the mine, and determined what they consider fair terms upon which the various pitches should be *set* or granted. The men, on the other hand, have also come to an estimate of the terms they will offer to execute the work, taking all the usual chances. The chief captain now puts up the various pitches to auction, the biddings being downward. The captain generally names a price above that which ought to be given, and the miners bid downwards against each other, if they please, until the fair price is agreed upon, which is generally nearly understood beforehand, as all parties are fairly aware of what it ought to be. It may happen, indeed, that the miners at work on the spot, just before the setting-day, have discovered appearances which lead them to think that they may take the pitch on apparently low terms, so that they may gain largely by breaking an amount of ores which the captains may not consider probable; but this occurs rarely. The pitches are commonly taken by a number of men proportioned to the work to be executed, but though they often vary from two to twelve, it is usually contrived that there shall be at least two for each spell or core of eight hours, the usual division of the spells. This partnership is generally termed a *pair* of men, whatever the number may be, and one commonly acts at the setting-days as a bidder for the rest. When no one is disposed to bid lower, the captain flings a pebble to the *taker*, as he is styled, and he is proclaimed, and his bargain entered. It is seldom that the captain fails to find a taker at a fair price, but should he do so, the work is referred to some future setting-day. As soon as the pair is chosen, they are entitled to an advance of money for subsistence, and hence called *'sist-money*, until the period of their taking is completed. The setting-day is a holiday at the mine, and generally occurs every two months. Before proceeding to the business of bidding, the rules are read, and fines attached for breach of regulations.

By obtaining a certain sum in the pound for the ores when sold, the tributers are interested in sending up as much ore to the surface as they can during their occupations in the various pitches, and hence their interests become those of the mine generally. If a pitch should turn out better than was expected, they may gain considerably; but should it become poorer, they suffer loss in proportion. The tributers pay for their coals, candles, and gunpowder; for the use of the machinery by which the ore is raised to the surface; and the wages of those who wash and prepare the ores for sale.

It is not known when this system of *working on tribute* was first introduced. Mr. John Taylor remarks, on the working of this system, that "the mine-owners, having by their capital, and the skill of their agents, discovered the ore, formed approaches to it, drained off the water, and ventilated the places for working, admit co-adventurers for a time, whose interest it is not only to search out every piece of ore that can be profitably worked, but so to detach it from the matter with which it is mixed, as to incur the least possible expense in after-processes. The payments they make cause them to look with a jealous eye on all cost incurred by others through whose hands the ores may pass, and thus to tend to a general economy, and perhaps, above all, discoveries are much extended by speculation among the men, who risk their labour only while they bring into play the judgment which the habit of constant observation enables them to form."

Tut-workmen are those who execute work by the piece, generally calculated by the fathom. In this manner shafts are sunk, adits driven, and the labour usually performed in those parts of the mines which do not produce ores, executed. Tut-work is also employed upon the lode itself, though from the advantages generally considered to arise from the tribute system, the latter is employed as much as possible in mines at full work.

Day *labourers* are generally employed on the surface in dressing ores, and in occupations of the like kind, though in some mines day-labour is also used underground. A large proportion of the surface labourers consists of women and girls.

The comfort of those employed in the mines, has of late received far more attention than formerly, and the places where the women and girls pound or pick the ores on the surface, are now nearly always defended from the weather. Barracks are provided for the miners to change their underground clothes, and arrangements are, in some cases, made for drying those which have become wet during work. The miners are liable, from their occupations, to many accidents and diseases, and it is, therefore, usual to provide medical attendance for them out of a fund raised by the miners themselves. In the deep mines they suffer much from climbing the ladders to the surface, as also from the great changes of temperature experienced in winter, when, after working several hours underground, in a temperature from 70° to 90°, they walk to their homes in the cold.

So extensive are some mines, that it frequently requires an hour to reach the surface, after work is done.* The ascent and descent is by ladders, each fifty feet long; which were formerly, and still are in some places, perpendicular to the sides of the mine; but as the mines have been worked deeper, the ladders have been shortened to half that length, and placed as slopingly as possible, to ease the miner, whose weight is thus rendered more dependent on his feet than on his hands. At the foot of each ladder is a platform, called a *sollar*, with an opening, or man-hole, leading to the next ladder beneath. Considerable attention has been paid in Cornwall to the practicability of providing machinery by which the labour of climbing the ladders may be avoided —a plan which has been successfully adopted in the deep mines of the Harz. At the Tresavean, the deepest mine in Cornwall, which is worked at a depth of upwards of 300 fathoms,* a machine has been erected for raising or lowering the miners as much as 240 fathoms.

---

* The workings of the Consolidated Mines alone extend sixty-three miles underground, or 55,000 fathoms.

An extensive mine must be at all times an object of admiration to a thoughtful visitor. From the bright sunshine and smiling prospects of the surface, he suddenly plunges into a dark abyss, his solitary candle serving apparently to make the darkness more terrible. Descending these perpendicular ladders reeking with wet mud, and the rocky walls through which he passes streaming with moisture; the air gradually becoming hotter and moister; his ears assailed by the roar of many waters, and the clanking of machinery; and every now and then the discharge of gunpowder reminding him of the discord of a battle-field; he at length lands upon one of the levels, and gropes along the dark tunnel until the gradually increasing light, and noise, and bustle, disclose the scene of actual mining operations. The vein of ore sparkles from the rocky wall, and is a beautiful object; the miners are tracing it in a slanting direction, and forming a *winze* down to a lower level, which can be reached by proceeding over heaps of fragments of rock. The ascent by the perpendicular ladders is by far the most difficult and laborious part of the undertaking, and no one who has attempted it can repress a feeling of gratitude to the inventor of the machinery for raising the miners to the surface.* But some of the Cornish mines are even more impressive in their character than those to which the writer here refers. In the Saint Just district, near the Land's End, the directions of the veins and the distribution of the ores direct many of the mining operations towards the sea. Several of the mines are worked to some extent beneath the bed of the Atlantic, and the breaking of its waves is distinctly audible to the miner whilst at work. In Little Bounds, Botallack, and Wheal Cock, the miners actually followed the ore upwards to the sea; but the openings made were very small, and the rock being extremely hard, a covering of wood and cement in the two former, and a small plug in the latter mine, sufficed to exclude the water. "In all these, and in Wheal, Edward, and Levant," says Mr. Henwood, "I have heard the dashing of the billows and the grating of the shingle overhead, even in calm weather. I was once, however, underground in Wheal Cock during a storm. At the extremity of the level seaward, some eighty or one hundred fathoms from the shore, little could be heard of its effects, except at intervals, when the reflux of some unusually large wave projected a pebble outward, bounding and rolling over the rocky bottom. But when standing beneath the base of the cliff, and in that part of the mine where but nine feet of rock stood between us and the ocean, the heavy roll of the larger boulders, the ceaseless grinding of the pebbles, the fierce thundering of the billows, with the crackling and boiling as they rebounded, placed a tempest in its most appalling form too vividly before me to be ever forgotten. More than once, doubting the protection of our rocky shield, we retreated in affright; and it was only after repeated trials that we had confidence to pursue our investigations."

---

* Dolcoath mine is more than 210 fathoms below the adit-level, which is 30 or more fathoms below some parts of the surface. The main shaft of the Fowey Consols is about the same depth.

---

* In the autumn of 1847 the writer visited the mines of Freiberg, in Saxony, so long celebrated for their rich veins of silver, lead, copper, and cobalt. He descended the Himmelfahrt mine, to which the preceding lines refer.

The foregoing details will be assisted by reference to the frontispiece, which represents a plan and section of a portion of Dolcoath mine. In the upper figure or plan, the ground is supposed to be either removed or transparent, so as to show the underground levels, adits, &c. The lines representing the levels driven upon the lodes, have numbers attached, which give the respective depths beneath the adit;* so that if perpendicular lines were let fall from this level upon such lines, they would cut them at the various depths marked, such as 60, 70, 80, 100, or any other number of fathoms. It will be observed by the increase of the numbers marked on levels to the southward, that the dip or underlie of the lode must be in that direction; and further, that lines representing equal depths are much closer to each other in some places than in others, showing that the lode approaches more towards the perpendicular in those places than in others. In reality, these lines are far more irregular than they are represented in the plan. Thus, while the engine shaft is inclined with the dip or underlie of the main lode, the Gossan shaft is sunk perpendicularly; so that cutting the plane of the lode somewhere near the 125 fathom level, cross-cuts are made to communicate with it at less depths from the north, and at greater depths from the south, in order that the ores raised at these levels may be brought to it, and lifted to the surface. Several other cross-cuts will be observed on the plan, some of which are merely for the purpose of uniting the various parts of the mine conveniently together, while others act as channels for draining the waters, so that they may be brought to the most convenient place for pumping. Cross-cuts of this kind will be seen between the North Entral lode and the main lode at the various depths of 40, 70, 80, 100, and 120 fathoms; and the levels upon a southern lode, known as the *Caunter*, will be seen to cut across or abut upon those of the main lode, where the two lodes meet.

---

* In most of the Cornish mines the depths are reckoned from that of the adit, and not from the actual surface of the country, which often undulates considerably, so that a given level may be 100 fathoms beneath such surface at one place and only fifty fathoms at another. By thus reckoning from beneath a well-known level such as that to which the water is pumped up, a more accurate idea may be obtained of the depth of the workings than by reckoning from the surface.

This plan, therefore, shows the mode in which the levels on the lodes, the shafts, the adits, and cross-cuts occur. We now turn to the section, in which the lines of levels and letters of reference correspond with the plan. If we suppose the south side of the main lode at Dolcoath, and consequently, as it underlies south, the upper or *hanging* wall to be removed, we should have such a section of the workings as is here represented. In this section, those portions which have been cut for galleries in the levels, the shafts, and where branches or accumulations of ore have been found, are left blank; and those parts in which the rubbish of the workings (called *deads* or *attle*) has been thrown back, and so arranged that the galleries or levels and the shafts should pass freely through them, are represented as composed of broken fragments. The killas or slate remains white, while the granite is dotted. We see that this main lode cuts into granite in its eastern prolongation; and a tabular piece of granite, forming a projecting mass or vein from that rock, at a higher level, being cut by the lode at a short distance from the main mass of granite, appears as if separated entirely from it amid the slate. The bunches of ore will be observed to have occurred very irregularly, and the places which they occupied, in a great measure, will be seen filled up with the rubbish taken from the non-productive workings of the mine. Levels on the east have been driven into the granite in search of bunches of ore, and in both directions the search was abandoned.

It will be seen that the *sump* or lowest part of the engine shaft forms the lowest part of the mine, as already noticed. At the time when this plan was made, the ores were drawn up to the surface by four shafts, by the three steam-whims; but the position and number of the shafts varies with the state of the mine, so that many shafts may exist which are not used for drawing ores or for pumping. This is now the case with several shafts on the main lode at Dolcoath, including an old pumping-shaft. As every shaft has its name, and every level is known by its depth, the position of work in any part of the mine is at once comprehended by all. A mine, in fact, resembles a town, of which the streets are known by names, and the houses by numbers.

The various cross-courses traversing the lode are also marked and named; and although these, when they heave the lode considerably, bar the progress of the miner, or cause a great increase in the influx of water into the mine, are injurious, at other times they are highly useful by keeping out the water of a neighbouring mine. In the latter case they are in consequence preserved uncut, as in Dolcoath mine, where the great cross-course on the east of the lode is untouched, except at the adit-levels which traverse it. This cross-course has cut through the lode, the continuation of which is worked in the adjoining mine of *Cook's Kitchen,* and heaved it, so that a line prolonged from one would not strike the other; and it lately kept out a body of water which had accumulated in the old workings at Cook's Kitchen. Such main cross-courses, which frequently bound setts, and thus often separate old mines, are carefully preserved, so that the failure of one mine does not cause its waters to pour in and deluge the other, beyond the power of its engines to clear it. In different parts of the same mine, the cross-courses are in part preserved, in order to keep out the water from the deeper levels, when this can be done conveniently. On the west of the section the workings do not reach a cross-course beneath the forty-fathom level, though from a shaft having been sunk upon it, the workings which reach it on the east side are deeper. Cross-courses are found extremely useful for driving adits upon, and as they generally cut the lode at considerable angles, the work thus carried on exposes a good section of the *country* as it is termed, or rocks on both sides, and consequently of any lodes which may there occur.

The distances at which the levels have been driven from each other are very irregular upon this lode, except in the lower workings, beneath those of 150 fathoms, which have been made more in accordance with the modern practice of forming them ten fathoms from each other, as will be seen in the

Digitized by Google

section, where we find complete regularity in this respect from the adit to the ninety-fathom level. The workings beneath that level have been driven for discovery, and at greater distances to save expense. On this *caunter* or *contra* lode, which is worked through *Harriett's* lode up to the main lode, considerable expense was incurred in driving levels, both in the depth and towards the eastward, in search of ore, which was unattended with success. These heavy expenses on account of discovery can only be profitably borne by mines of a certain magnitude, which, throwing up a fair general amount of ores, can afford to put aside a certain proportion of the profits for discovery.*

---

* The writer is indebted for several particulars, respecting the tin and copper mines of Cornwall, to the valuable official Report on the Geology of Cornwall, by Sir Henry De la Beche.

R. CLAY, PRINTER, BREAD STREET HILL.

THE USEFUL ARTS
AND
MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF
COPPER, TIN, LEAD, AND ZINC (*Concluded*);
AND THE
MANUFACTURE OF BUTTONS, PINS, TIN PLATE, SHOT, &c.

DRESSING THE ORES.

After the ore has been raised to the surface, it undergoes various operations before it is fit for the smelter. Tin ores are generally carried through all the operations necessary for their purification previous to being smelted. The smelter has therefore only to carry them twice through the furnace: by the first melting they are brought into a metallic state; and by the second, the metal is sufficiently purified. The ores of copper, on the contrary, are only brought by the miner into the state which makes them fit for roasting or calcining: in this state they are sold to the smelter, by whom they are alternately roasted and smelted several times before any appearance of copper is visible; and after they are reduced to metal, it undergoes three purifying operations before it is fit for the market. On this account, although a given quantity of average copper ore, as it comes from the lode, is much richer and more valuable than an equal quantity of tin ore in the same state, the tin ore, when prepared for sale, is at least seven times richer than that of copper.

The tin of the Cornish mines is nearly all in the state of peroxide, of variable purity; it is sometimes crystalline, and at others mingled with much earthy matter. Copper ore occurs in various forms, such as *copper pyrites*, or bisulphuret of copper: this, when pure, contains nearly equal parts of sulphur, copper, and iron; but in the lodes it is often mixed with other substances, such as sulphuret of zinc, iron, and arsenical pyrites, quartz, chlorite, and other minerals; so that, although considerable masses of pure ore are occasionally met with, it is usually so much mixed as to require dressing previous to sale. The next important Cornish copper ore is the sulphuret, or *grey ore* of the miners. This contains upwards of 77 per cent. of copper, 20 of sulphur, and very little iron. The *black ore* is also very valuable, and is almost a pure oxide, containing nearly 80 per cent. of copper, and is occasionally met with in such abundance as greatly to increase the value of the mine.

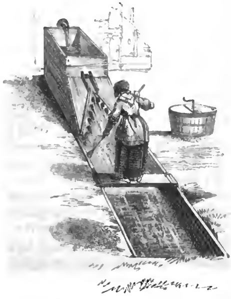
But first, with respect to the dressing of tin ores.* When raised from the mine, the first operation is to break in pieces, about as large as a man's fist, any stones that may exceed that size, and to reject such portions as do not contain more ore than will repay the cost of dressing. In some stones the tin ore is scarcely perceptible to the eye; in which case the workman from time to time reduces a small quantity to a fine powder, and by repeatedly immersing it in water, and shaking it to and fro on a shovel, the impurities are removed: by this simple operation, which is called *vanning*, the quality of the ore is roughly ascertained, as well as the size to which it must be reduced in order to free it from foreign substances.

---

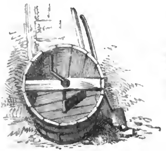
* Our information on this subject is chiefly derived from an elaborate paper by Mr. Henwood, in the Transactions of the Royal Geological Society of Cornwall. The engravings are from original drawings made on the spot.

The ore is now ready for the stamping-mill. This consists of three or four upright wooden beams called *stampers*, about ten feet long and eight inches square, to the lower extremities of which are attached pieces of cast iron, varying in weight from one hundred and a-half to four hundredweight and a-quarter. These are placed in a wooden frame, and alternately lifted up about ten inches by the cogs or wipers of a horizontal axle, which is moved round either by a water-wheel or a steam-engine. Where the latter power is used, the number of stampers is increased to 24, 36, and even 48. The ore is placed on an inclined plane close to the bottom of the stampers, and as these are lifted up, a portion of it slides down directly beneath them and is crushed by their fall. The aperture through which it is admitted is of such a size as to prevent the entrance of so much as would impede the action of the machine. The second stamper is lifted an instant before the fall of the first, and the third before that of the second. The fall of the first forces a portion of the ore beneath the second, and that of the second beneath the third: the fall of the last forces such of the ore as has been sufficiently pulverised through a copper or iron grating, placed opposite the aperture by which the ore is admitted under the stamper. The whole arrangement is copiously supplied with water, which assists the progress of the tin through the grating. Adjoining the stamping-mill, and connected with the grating by a conduit, are two pits: the ore after passing through the grating runs into the nearest pit, in which the rough ore lodges, as well as the heavier part of that which has been reduced to powder, and known by the name of *slime*; this rough ore when dressed is called the *crop*. The remainder, with the lighter slime, which, passing through the first pit, is retained in the second, when dressed, is called the *leavings*, and varies in quantity from one-fourth to one-seventh of the whole. Now begins the process of purification, so far as to prepare the ore for being smelted; and this comprises a large number and variety of operations, but the great principle of the whole is that of subsidence by the superior weight of the metallic portion as compared with the stony and earthy matters which are to be got rid of.

The first operation on the crop is called *buddling.* The buddle is a wooden case about 8 feet long, 3 wide, and 2½ feet deep, fixed in the ground, one end being a little elevated; on the rim of the higher end is fixed a board, called the *jagging-board*, from 12 to 16 inches wide, extending from side to side, and somewhat more inclined than the buddle. The operator, who may be a man or a woman, spreads the ore on the jagging-board, and with his shovel cuts it into small furrows parallel to the length of the buddle: a small current of water, which is admitted at the head of the buddle, is made to flow equally on every part of the board. The action of the water carries all the ore into the case, where the richer and finer portions subside near the head, while the rougher and lighter portions are carried towards the lower part. The workman, who



stands on a plank over the buddle, about three feet from the head, assists the action by gently passing the foot, or a tool held in the hand, along from side to side. When the ore is rough, this operation is sometimes performed with the naked foot; but when the particles are very fine, the foot is usually shod with a smooth piece of wood called the *brogue*. This process is continued until the buddle is full. Its contents are then divided into three or four parts, according to the quality of the ore; the richest part, termed *heads*, is near the head of the buddle; the *tails*, or worst part, being near the foot; the intermediate portions are called *first* and *second middle heads*. These are again separately buddled, until the ore at the head is freed from the poorer and rough particles. The *heads* are then *tossed* or *tozed* in a kieve or large tub, about one-third filled with water, which one workman stirs about rapidly while another gently puts in the ore with a shovel. The tub is furnished with a stirrer, the construction of which will be seen in the first of the two following engravings. The stirring is continued till the vessel is nearly full: it is then stopped, and the outside of the kieve is struck smartly with a hammer until the ore has subsided: this is called *packing*. By this process the most impure parts are brought to the top, whilst the remainder subsides in the order of its weight The whole is now divided horizontally



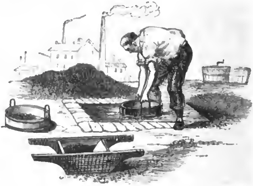
into two or more parts, the lowest division being fit for smelting, unless it is found to require roasting, in order to get rid of the ores of iron, copper, and zinc, which is often the case. The upper division, called *skimpings* (skimmings), are again buddled and tossed; the tails are thrown amongst the *leavings,* and the ore in the lowest part of the kieve is again fit for the smelting or the calcining-house.

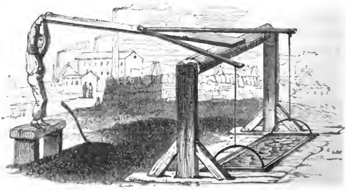
The first and second middle heads are also subjected to operations which differ more or less from those just described. One of these operations, called *dilluing,* is performed with a hair-bottomed sieve of close texture, into which an assistant puts about thirty pounds of ore: the operator then immerses it in a kieve about two-thirds full of water, and by moving it round, as well as up and down, and from side to side in the water, the small and light particles become suspended, and by inclining the sieve, they pass out of it and subside at the bottom of the kieve: the sieve is regularly replenished from the ore-heap by the assistant, and the operation is continued. Whether the ore in the sieve is now fit for the smelting-house, is ascertained by the process of *vanning* already described; but if not sufficiently pure, the next operation, supposing it does not require to be roasted, is *tying*; but as most of the tin ore of Cornwall requires roasting, this operation is the next part of the process.

The object of roasting is to get rid of ores of copper, iron, or zinc, mixed with the tin ore. The furnace in which the ore is *burnt,* as the miners call it, is a common reverberating furnace: it is raised to a dull red heat, and then about seven hundredweight of the ore is put into it through a hole in the top. It is allowed to remain for about an hour, to get rid of the moisture imbibed in the previous processes, and is then spread over the furnace for about four feet in length nearest the fire, and by means of an iron rake is turned about every half hour, that the whole may be equally exposed to the action of the fire. This is continued until the ore ceases to give out whitish fumes, or, when turned, to exhibit bright sparkles; it is then withdrawn through a hole now uncovered in the bottom of the furnace, and allowed to cool. It is then sifted, and after being again tossed, buddled, and again tossed, it is ready for the smelter.

But some kinds of ore, after being roasted, require *tying.* The *tye* is a long narrow inclined furrow through which passes a stream of water, three or four times more copious than that used for buddling. The ore being placed at the head, is agitated with a broom, and the rough and lighter particles are carried to the lower part of the tye. The ore at the head, unless it requires to be again diluted, is fit for the smelting-house. The remainder, if very poor, is thrown among the leavings; but if otherwise, it is exposed to another operation called *jigging.*

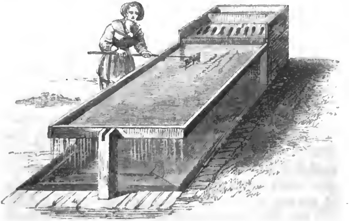
This is performed by plunging a copper-bottomed sieve, containing two or three shovelsfull of ore into a vessel of water. The operator, holding the sieve in his hand, gives it both a vertical and rotatory motion, taking care that it be never lifted above the surface of the water; by this means the different parts arrange themselves in the sieve in the order of gravity; the lighter portions, being brought to the top, are scraped off and considered as *leavings,* and a fresh supply of ore is thrown in and jigged, until the weight of the richer part at the bottom of the sieve becomes too great for the operator; it is then taken out in a state fit for smelting. The *jigging-machine* is sometimes used in this operation, but more commonly in the dressing of copper and lead ores. Its construction is very simple, and will be understood by reference to the annexed engraving.





The foregoing operations apply to the *crop;* the *leavings*, consisting of the *slime*, the *tails* of the buddles, the *skimmings* of the skimpings, and the *skimmings* of the jigging,—are subjected to a series of operations not differing in principle from those already described, but bearing different names, such as *trunking, framing,* or *racking,* and varying in the methods adopted. Our space will only allow us to describe one of these operations, viz. *framing.*

In framing or racking, the *frame* is a flat piece of wood, about eight feet long and five feet wide, with a rim five inches high round it. This is suspended in an inclined position on pivots, but is fastened by a kind of latch; at the upper end is a jagging-board, similar to that of the buddle, which is connected with a frame by a moveable sloping piece of wood, to prevent the ore from falling between the board and the frame; below the frame are two boxes, which, being placed end to end, extend its whole length: at the lower end of the floor a vacancy of two or three inches leaves an aperture for the escape of water. The operation is usually conducted by a woman as follows:—she spreads on the jagging board from two to three quarts of the *slime* obtained in the previous operation of *trunking,* and with a small toothless rake makes in it small furrows, in the direction in which a stream of water runs which is let in upon the jagging-board. By this means the ore is carried from the board to the frame; the richest part rests at and near the head, and the poorer parts farther down; the impurities are carried off by the water, and escape at the bottom. The woman runs the



rake across the frame to agitate the ore, and when the richer part has sufficiently accumulated, the jagging board being swept clean, the latch is lifted, and the frame turned on the pivots from a horizontal to a vertical position, and the ore is swept or washed into the boxes beneath, the best into the upper and the inferior into the lower box. It is of importance that the water should pass of equal depth and velocity over every part of the frame, or the different parts of the mass will be mixed with each other, and some of the ore be carried off with the waste.

Very little improvement has been made in the mode of dressing tin ores for nearly a century; but of late years improved machinery has been introduced at some mines.

Copper ores.—When these are brought to the surface, they are divided into three portions: the first, consisting of pieces about the size of the fist, called *spalling stuff*; the second, termed *picking rough*, consisting of such smaller pieces as will not pass through a sieve, named, from the size of the meshes, a *three-quarter-inch griddle*; and the third, of all that passes through the sieve, called *shaft small*.

The larger pieces being broken to about an inch and a half square, are mixed with the picking rough, and the whole divided into *prills*, or lumps of pure ore; *dradge*, or ore mixed with other substances; and *halvans* or *leavings*, which contain but a small quantity of ore. The prills are broken into pieces of about half an inch square, which is performed by females with large flat-polled, two-handed hammers; this portion of the ore is then ready for the market.

If the dradge contain but little iron pyrites, it is broken to a still smaller size than the prills, and then jigged in a sieve of about five holes to the square inch. By this means it is separated into four parts: 1. That which passes through the sieve, called *hutch-work*, which is usually fit for sale. 2. That portion occupying the bottom of the sieve, called *ragging*, which is also in a marketable state. 3. The middle part of the contents of the sieve, which is again broken and jigged. 4. That at the top of the sieve, which is put among the leavings.

If the dradge contain much iron pyrites, it is *picked* by females and children; the pieces being broken to about five-eighths of an inch square, and the impurities picked out by hand.

By continuing these operations of picking, breaking and sifting, the ore is rendered fit for sale. Some of the ores are so soft that exposure to water would occasion loss. The leavings or refuse are, however, sometimes stamped and buddled in the same manner as tin ore.

The method of selling copper ores, as described by Jars in 1765, applies in some respects to the present day. The Copper Smelting Companies of Wales, Bristol, and other places, have agents in Cornwall who make purchases. "When there is ore to be sold in a mine, the agents are informed that on such a day samples will be taken. Each agent then goes to the mine on the day appointed, and from each of the heaps of ore, one is made the quarter of the quantity to be sold. From this quarter the samples are taken after the ore has been well mixed. Each of the agents then puts some of the ore into a small bag, about the measure of a quarter of a bottle, in order to make the assay, on which the price is fixed; the result of which is kept a profound secret until the sale takes place. This generally follows about a fortnight after the samples have been taken, when the adventurers in the mines, or their agents, and the agents of the Smelting Companies, assemble and dine together at the charge of the lord or proprietor, whose portion of ore is sold with the others, since he takes his share in money. Each of the agents, seated with the adventurers round a table, gives in a paper or ticket containing his offer for each kind of ore, specifying the weight of each heap, always expressed in tons; writing, for example, 18 tons of ore, at 3*l.* or 6*l.* All the papers are then read aloud, and each person takes a note of the offers which have been made, upon which the purchaser makes his engagement to pay in a given time."

The sales now take place weekly at Truro, Redruth, or Pool, on what are called *ticketing days*, and it is usual, after the results of the last sale are published, to announce those which are to take place at the two next ticketing days, distinguishing the mines and the number of tons of ore (of 21 cwt. to each ton), which each mine intends to sell. When two different Smelting Companies offer the same price for the same parcel of ore, it is usual to divide it equally between them.

In selling tin ores, the system of ticketing has of late years been introduced. The ticketing sales take place at Redruth and Treloweth commonly twice a month, and alternately at these two places.

LEAD ORE.—When the lead ore is raised to the surface, it is sorted out into three parcels, called *knockings*, *riddlings*, and *fell*, the last-named being that which passes through an inch iron-wire sieve, in which the riddlings remain; the knockings are the larger pieces of spar or stone with ore intermixed. The dressing of the ore does not differ in principle from that already described for tin; it is, however, much less elaborate, and many of the processes are called by different names. The buddling is carried on with the water of a running stream, which frequently has the effect of poisoning it for several miles in its course.

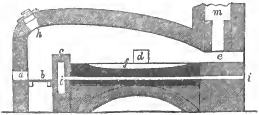
SMELTING THE ORES.

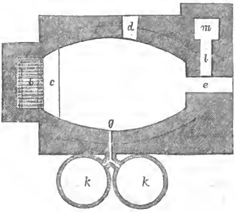
THE revenue of the Duchy of Cornwall being in great measure derived from the coinage of tin, the law required, previous to the act passed in the first year of the present reign (already noticed), that all the tin raised within the duchy should also be

Digitized by Google

smelted therein. The smelting of tin ore requires very little fuel: the smelting of copper a larger quantity; the latter is, therefore, smelted in South Wales, where fuel is abundant; and the vessels which convey copper ores to Swansea and Neath, return laden with fuel from Wales to Cornwall, for the use of the engines of the mines, for smelting tin ores, &c.

The tin-smelting works usually belong to persons who do not possess mines, but purchase the ores at the sales already noticed. The smelting is carried on in reverberatory furnaces, of which the following is a common form:—The first figure represents a section, and the second a ground plan; *a* is the fire door, through which the coal is placed upon the grate *b*; *c* is the fire bridge; *d* the door for introducing the ore; *e* the door through which the ore is worked upon the hearth *f*; *g* the stoke-hole;





Digitized by Google

h an opening in the vault, to secure the escape of the fumes up the chimney; *i*, *i*, air channels for admitting cold air under the fire-bridge and hearth, to protect them from the great heat above; *k*, *k*, are basins into which the melted tin is drawn off; *l* is the flue, and *m* the chimney. The ore is mixed with small coal or culm, and a little slaked lime as a flux, each charge of ore varying from 15 to 24 cwt.; and it is damped with water, to prevent the draught from sweeping any of it away when first introduced. As soon as the furnace is charged, the doors are closed and luted, and the heat gradually raised; for if too fierce at first, the oxide of tin would form an enamel with the quartz of the gangue or vein-stone. In the course of six or eight hours the reduction of the oxide is generally completed; the door of the furnace is then removed, and the melted mass worked up, to complete the separation of the tin from the scoriæ. The scoriæ are then removed with an iron rake, and divided into three sorts; the first, containing about three-fourths of the whole, is thrown away as refuse; the second sort contains about 5 per cent. of tin, in small grains, and is sent away to the stamps; and the third sort, or that last removed from the surface of the smelted tin, is set apart to be smelted over again, as it contains a good deal of grain tin. When the scoriæ are cleared away, the channel is opened which leads to the basins *k*, *k*, into which the tin now flows. Here it is left for some time, that the scoriæ which may still be mixed with the metal may separate. The tin is then lifted out in iron ladles, and poured into cast-iron moulds, and before it solidifies, a piece of wood is plunged into it, by which the ingot is drawn out when cold.

By this process of smelting, the tin ore is deprived of its oxygen, fused and cased into solid blocks. In this state the tin is still alloyed with iron, copper, arsenic, sulphur, and a few other matters in small quantity, all of which are got rid of by *refining*. This process is conducted in a reverberatory furnace, similar to that employed in smelting the ore. The blocks are arranged on the hearth of the furnace, near the bridge, and moderately heated: the tin melts and flows away into the refining basin. After a time, the blocks cease to afford tin, and most of the impurities remain behind on the hearth. Other blocks of tin are then arranged on the remains of the first, and the process is continued for about an hour, until the refining basin contains about five tons of melted metal. The second part of the process now begins. Billets of green wood are plunged into the tin in the refining basin, the heat of which disengages from the wood a quantity of moisture and gas, and gives to the tin the appearance of boiling, causing a sort of froth to rise to the surface, and the most impure and dense portions to fall to the bottom. The froth, consisting chiefly of metallic oxides, is skimmed off. When the tin has been *boiled* about three hours, the wood is removed and the tin left for about two hours to settle. It separates into different portions, the upper portion being the purest, the middle less pure, and the lowest portion most contaminated with foreign metals. The tin is then lifted out in iron ladles, and poured into moulds. The blocks first cast are of course the purest; those last cast, are so impure that they require a second refining. The moulds in which the tin is cast for the market are usually made of granite, and of such capacity that each block shall weigh a little more than 3 cwt. This metal is called *block-tin*, and the purest kind, *refined tin*. The scoriæ and dross produced in the smelting and refining are subjected to distinct processes to extract as much of the metal as possible. Tin is also melted by wood charcoal, whereby a much purer metal is obtained than where coal is used; but for this purpose the better ores of the stream works and the finer tin sands are employed. The block-tin thus formed, produces what is called *grain-tin*; a block of tin is heated till it becomes brittle, when it is raised to a considerable height, and allowed to fall, whereby it is broken to pieces, which appear like elongated grains or tears massed together.

SMELTING OF COPPER ORE.—It has been already stated that the copper ores of Cornwall and Devon are conveyed to Wales to be smelted, on account of the supply of fuel in the latter country. By this arrangement, the smaller quantity of material is carried to the greater—the ore to the coal—and the vessels load back coal for the service of the mines. The principal smelting works are situated on the navigable rivers of Swansea and Neath. The smelting processes consist of alternate calcinations and fusions, the object of the former being to expel volatile matter (sulphur, arsenic, &c.) and to oxidize the metals previously combined with the copper, whereby the general fusibility of the mass is greatly increased. The furnaces in which the operations are conducted are reverberating, and of the usual construction. The *calciners* are from 17 to 19 feet long, and from 14 to 16 feet wide; the *melting* furnaces are from 11 to 11½ feet long, and from 7½ to 8 feet wide: the form of the calciner is hexagonal; the melting furnaces are oval, flattened at one end.

The various ores which are discharged at the smelting works are mixed in different proportions, according to their quality and contents, so that in the smelting operations they act as fluxes upon each other. The mixed ore is conveyed to the works in wooden measures which hold a hundredweight each. The smelting processes are eight in number:—

1. *The calcination of the ore.* A charge of ore, of about 3 or 3½ tons, is distributed equally over the brick bottom of the calciner. The process continues twelve hours, and towards the end of it, the heat is as great as the ore will bear without fusing. To prevent this, and also to aid the extrication of the sulphur, the ore is frequently stirred during the

operation. When this process is over, the charge is drawn out through a hole in the bottom of the calciner, and if it has been well conducted, the ore is black and powdery. During the calcination, the arsenic is partially expelled and the sulphur got rid of, in the form of arsenious, sulphurous, and sulphuric acids, and the copper and iron are both partially oxidized.

2. *Melting of the calcined ore.* — The furnace is charged through a hopper at the top. When the charge is spread over the bottom of the furnace, the door is put up and well luted. Some slags, from the fusion of what is called the waste metal, are added, not only on account of the copper they contain, but to assist in the fusion of the ore. In this operation, the object is to melt the charge, and when this has taken place, the door of the furnace is removed, and the liquid mass well *rabbled* or stirred, to allow the metallic sulphuret to separate from the earthy matter. When the latter flows on the surface, it is skimmed off, and fresh charges of calcined ore are added till the metal collected at the bottom of the furnace is as high as the furnace will admit without flowing out at the door. The tapping-hole is then opened in the side of the furnace, through which the metal flows into a pan placed in a pit of water. It thus becomes granulated, and the pan is raised by a crane. In this process a great proportion of the earthy matter and iron of the ore is got rid of. The granulated metal generally contains about one-third of copper, or is about four times richer than the average ore: it now consists chiefly of copper, iron, and sulphur. When the ores are refractory, they are rendered more fusible by the addition of fluate of lime (fluor spar). In this state it is called *coarse metal.* The slags obtained in this operation are broken up, to see whether they contain any copper, and if they do, they are returned to the smelter to be remelted. This process is carried on day and night; and from five to six charges are worked during the twenty-four hours.

3. *Calcination of the coarse metal.* — This opera-

tion is conducted in the same manner as the calcination of the ore; the charge is nearly of the same weight, and remains twenty-four hours in the furnace; the great object is to oxidize the iron; the heat during the first six hours is moderate, and afterwards increased to the end of the operation. The result is *calcined coarse metal.*

4. *Melting of the calcined coarse metal.* This is performed in furnaces similar to the melting furnace. To the calcined metal are added some slags from the last operations in the works, which contain some oxide of copper, as likewise pieces of furnace bottom, impregnated with metal. In this operation, the oxide of copper in the slags becomes reduced by a portion of the sulphur which combines with the oxygen, and passes off as sulphurous acid gas, while the metal thus reduced enters into combination with the sulphuret; sometimes a little uncalcined ore is added to assist the operation, which it does by the sulphur contained in it. After the slag is skimmed off, the metal is either tapped into water or into sand beds, according to the mode of treatment to which it is to be subjected in subsequent operations. In the granulated state it is called *fine metal;* in the solid form, *blue metal,* from the colour of its surface. The former method is practised when the metal is to be brought forward by calcination: it then contains about 60 per cent. of copper, and is called *fine metal.*

5. *Calcination of the fine metal* is conducted in the same manner as the calcination of the coarse metal, and lasts twenty-four hours.

6. *Melting of the calcined fine metal.* This is effected in the same manner as the melting of the coarse metal, and the resulting product contains 80 to 90 per cent. of copper, and is called *coarse copper.* It is run into pigs for the next process.*

7. *Roasting of the coarse copper.*—This is chiefly

---

* The fifth and sixth operations have of late years been omitted in the smelting houses of Messrs. Vivian. The blue metal of the fourth operation is run into pigs and roasted, as in the seventh operation.

Digitized by Google

an oxidizing process. The furnaces in which it is performed are called *roasters,* and are of the same kind as the melting furnaces. The pigs of coarse copper obtained by the last process are put into the furnace, and exposed to the action of the air at a high temperature, which is gradually raised to the melting-point; by this process the expulsion of the volatile matters is completed, and the metals are oxidized; each charge is from twenty-five to thirty cwt. The metal is fused towards the end of the operation, which is continued from twelve to twenty-four hours, according to the state of forwardness when filled into the furnace, and is tapped into sand-beds. The pigs are then covered with black blisters, in which state the copper is called *blistered copper.* In the interior of the pigs, the metal has a porous, honeycombed appearance, occasioned by the gas liberated during the ebullition which takes place in the sand-beds on tapping. In this state the copper is fit for the refining, as it is nearly free from all the sulphur, iron, and other substances with which it was combined.

8. *Refining, or Toughening.*—The refining furnace is similar in construction to the melting furnaces, and differs only in the arrangement of the bottom, which is made of sand, and laid with an inclination to the front door, instead of to one side, as is the case in those furnaces in which the metal is allowed to flow out. The refined copper is taken out in ladles from a pool formed in the bottom, near the front door. The pigs from the roasting furnaces are filled into the refining furnace through a large door in the side. The heat is at first kept moderate, so as to complete the roasting or oxidizing process, in case the copper should not be quite fine. After the charge is run down, if there is a good heat in the furnace, the front door is taken down, and the slags skimmed off. An assay is then taken out by the refiner with a small ladle, and broken in the vice;

Digitized by Google

and, from the general appearance of the metal in and out of the furnace, the state of the fire, &c., he judges whether the toughening process may be proceeded with, and can form some opinion as to the quantity of green wood and charcoal required to render it malleable, or, as it is termed, to bring it to the *proper pitch.* The copper in this state is what is called *dry.* It is brittle, of a deep red colour, inclining to purple, of an open grain and a crystalline structure. In the process of toughening, the surface of the metal in the furnace is first well covered with charcoal; a pole, commonly of birch, is then held in the liquid metal, which causes considerable ebullition, owing to the evolution of gaseous matter. This operation of poling is continued, with an occasional addition of fresh charcoal, so that the surface of the metal may be kept covered, until, from the assays which the refiner takes from time to time, he perceives the grain, which gradually becomes finer, to be perfectly closed, to assume a silky, polished appearance in the assays, when half cut through and broken, and to be of a light red colour. He then makes further trial of its malleability, by taking out a small quantity in a ladle, and pouring it into an iron mould, and when *set,* beating it out, while hot, on the anvil, with a sledge hammer. If it be soft under the hammer, and does not crack at the edges, he is satisfied as to its malleability, or, as they term it, that it is *in its proper place.* He then directs the men to lade it out, which they do in iron ladles coated with clay, pouring it into pots or moulds of the size required by the manufacturer. The usual size of the cakes, for common purposes, is twelve inches wide, by eighteen inches in length.

The process of refining or toughening copper requires great care and attention on the part of the refiner, to keep the metal in the malleable state. Its surface should be kept covered with charcoal, otherwise it will *go back* between the rounds of lading, in

Digitized by Google

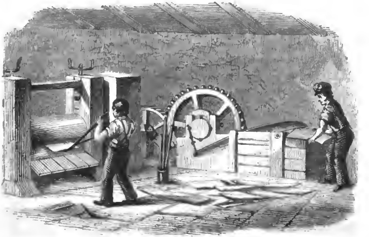
which case fresh *poling* must be resorted to: the cakes are allowed to cool in the pot, and others are laded thereon. Overpoling is to be avoided, as the metal is thereby rendered even more brittle than when in the dry state: its colour also becomes a light yellowish-red, and its structure fibrous. When this is found to be the case, or, as they say, it is *gone too far*, the refiner directs the charcoal to be drawn off the surface of the metal, and thus, by taking down the side door, and exposing the copper to the action of air, it is brought back to its proper pitch: that is, it again becomes malleable.

Copper in the *dry state* has a very strong action upon iron; the iron tools employed in stirring the liquid metal become very glistening, and wear away more rapidly at that time than when the copper has acquired its malleable state. The metal requires also, when *dry*, more time to become solid, or to cool, than when it is refined. When the proper refining point has been passed, another remarkable circumstance has been observed: the surface of the copper oxidizes with difficulty, and becomes uncommonly brilliant, reflecting clearly the bricks of the furnace-vault.

The fumes from copper smelting works are very injurious, both to animal and vegetable life, consisting, as they do, of sulphurous and sulphuric acids, arsenious and arsenic acids, various gases, and fluoric vapours, coal smoke, and solid particles mechanically driven into the air. Much of the injurious effect of these fumes upon the atmosphere has been obviated, by making them pass through horizontal flues of large dimensions, with many crossings and windings of the current, and exposure, during the greater part of the circuit, to copious showers of cold water. In this way, a powerful system of condensation is produced, by which the arsenic is deposited in the bottoms of the flues, and the sulphur acids almost entirely absorbed.

Digitized by Google

The form in which copper is prepared at the smelting works for the market, depends upon the use to which it is to be applied. Copper for brass-making is granulated, because in this state it presents a larger surface to the zinc or calamine, and combines with it more readily. This granulation is effected by pouring metal from the ladles in which it is taken out of the furnace into a large ladle, pierced in the bottom with holes, and supported over a cistern of water. The water may be either hot or cold, according to the form to be given to the metal. When warm, the copper assumes a round form, and is called *bean shot.* When a constant supply of cold water is kept up, the metal has a light ragged appearance, and is called *feathered shot.* Another form, called *japanned copper*, is to cast the metal into pieces, each about six inches in length, and weighing eight ounces; and as soon as the copper solidifies, to drop it from the moulds into a cistern of cold water, when, by a slight oxidation, the sticks acquire a rich red colour on the surface. This form is chiefly for export to the East Indies. When copper is required in the form of sheets, it is rolled hot, for which purpose it is cast into cakes of about twelve by eighteen-and-a-quarter inches in size, each weighing about ninety pounds. The cakes are put into muffles, and raised to a heat which depends upon the quality of the copper; but it is generally beyond a bright red heat. Each cake is then passed between strong cast-iron rollers, the rolls being forced nearer together after each passage of the cake between them: this process is called *breaking down*, and is continued until the cake is lengthened about five-fold. It has now become too cold for further rolling, and is cut by strong shears into pieces called *blanks*, of the required weight, which are heated in the muffle, and rolled out till their length becomes twice their breadth. They are again heated and doubled, and the two pieces are passed through the rolls together till they reach the required lengths; but they must be frequently heated between the rollings. When the sheets are thin, several thicknesses are rolled together. In the course of rolling, an oxide of copper is pressed into the surface, which is afterwards removed by dipping each sheet into a saline mixture, putting it into the muffle, and, when red-hot, plunging it into cold water, where the scale or oxide, suddenly contracting by the cold, falls off, and leaves the surface of the copper clean. By this process the copper is also softened, so that after the edges are trimmed with shears, the sheet is now fit for use. When sheet copper is required to be hard in texture and bright on the surface, it is rolled cold, after it has gone through the process of breaking down.



SMELTING OF LEAD ORE.—The chief or perhaps the only working ore of lead is the sulphuret, commonly called *galena*. In Derbyshire there is a specular variety of this ore, called *slick insides*, and when the rock pervaded by it is struck by the miner's pick, it often splits asunder with a kind of explosion.

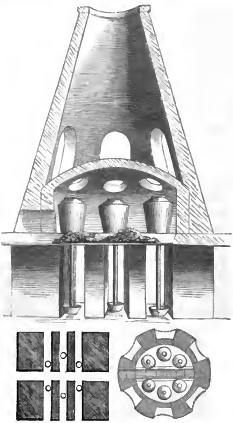
The smelting of lead ore is not a complicated process. The ore is heated in a furnace long enough to expel the sulphur, and to cause the earthy matters to separate in the form of scoriæ, which float on the surface of the melted metal, which is then run off into a large iron pan, and afterwards ladled into cast-iron moulds. It then forms *pig*-lead. The metal left in the scoriæ is extracted at another furnace, called a *slag-hearth*, and is also cast into pigs. In this state lead always contains a proportion of silver. In Derbyshire and Shropshire there is only an ounce, or an ounce and a half in every ton of lead; but in Devon and Cornwall there is as much as from twenty to thirty ounces. When the proportion of silver is sufficient to pay the expense of extracting, it is separated from the lead by a process called *cupellation*, which depends upon the property of lead to absorb oxygen from the air, and become converted into an oxide, under circumstances in which silver undergoes no change, but retains its metallic form. The lead is put into a *cupel*, which is a shallow dish, filled with a mixture of burnt bones and fern ashes pressed down, upon which the lead is melted, and a blast of air being made to play upon its surface, a yellow crust of oxide is formed: this is driven away, as fast as it appears, to the opposite side of the furnace, until nearly all the lead has been oxidized. The silver which remains behind still contains a portion of lead, which is separated by a repetition of the process. The litharge or oxide of lead produced during cupellation, is restored to its metallic state by heating it in contact with carbonaceous matter, to which it gives up its oxygen, and forms carbonic acid.

A less expensive process for extracting silver from lead was introduced by Mr. Pattinson, in Durham, founded on the observation that in a mass of melted lead crystals of the metal are formed as the temperature sinks below the melting-point, which crystals contain a much smaller proportion of silver than the remaining uncrystallized mass. The process is conducted in the following manner:—A number of iron pots, each capable of holding five tons of lead, are placed side by side, over separate fires. One of the pots is filled with lead, melted, and skimmed of its impurities: the fire is then put out, and the lead left to cool gradually. The crystals, as they are formed, are taken out in perforated ladles, which allow the uncrystallized portions to run through, and the crystals are transferred to the second pot, where they undergo a second melting and crystallization, and then to a third pot, from which the lead is cast into pigs, and sold as refined lead. The crystals are separated from the lead in the other two pots, until the uncrystallized residue is so rich in silver as to contain from two to three hundred ounces per ton; and from this portion the silver is extracted by cupellation.

One of the most useful applications of lead is in the form of sheets, which, from the low fusing point of this metal compared with that of copper, are formed with much greater facility than copper sheets. Sheet lead is cast upon an iron table, with a ledge running round the edges. The fused metal is first poured into a three-cornered iron vessel, placed at the head of the table, from which it is poured. The metal is then spread evenly over the whole surface, by means of a bar placed across the table, and resting on the ledges, the thickness of the sheet being regulated by the distance between the lower side of the strike and the table. By moving the strike forward, the lead is made to cover the table, and the surplus, if any, falls into a vessel at the foot of the table. A sheet of lead weighs nine cwt., so that its length and breadth will be great in proportion as its thickness is diminished, which is frequently done by passing it between rollers. Sheet-lead is estimated by the number of pounds weight in a superficial square foot.

SMELTING OF ZINC ORE.—The common ores of zinc are the sulphuret (also called *blende,* and, by the English miners, *black jack);* the silicate, called *calamine;* and the *sparry calamine,* or the carbonate.

The method of reduction of the ore depends upon the property of zinc being volatile at a high temperature. The ore is therefore distilled in crucibles or pots, six or eight in number, contained in a cupola furnace, arranged somewhat like the pots of a glass furnace, a part of the wall being taken down to *set* the pots, and then built up again. In the centre of the bottom of each pot is a hole which is closed with a wooden plug; the charge for each pot, consisting of six parts calamine and one part coal, is put in from above, through an orifice in the lid of the pot, which is left open after the firing, until the bluish colour of the flame shows that distillation has begun: the hole is then covered with a fire tile. The sole of the hearth upon which each pot stands is perforated beneath, so that they can be reached from below. When, therefore, the fire has heated



Digitized by Google

the pots, and consumed the wooden plugs, one extremity of a long sheet-iron pipe is put into each hole, the other extremity dipping into a vessel of water, which receives the condensed vapours of the zinc in drops, and in a fine powder, mixed with a little oxide. This distilled zinc is melted in an iron vessel, the oxide is skimmed off the surface, and the metal is cast into square bars or ingots.

In the first operation after each distillation, the iron pipes are removed, and the pots cleared out. A pot lasts, on an average, about four months, with five distillations in the course of fourteen days. The metal amounts to from twenty-five to forty per cent. of the ore.

By heating zinc to about 212°, it can be rolled into sheets.

MANUFACTURE OF BRASS.

Brass is a compound metal, consisting usually of an alloy of copper and zinc. *Gun-metal,* which is an alloy of copper and tin, is also sometimes called *brass;* and with a larger proportion of tin it is preferred for some kinds of machinery on account of its greater hardness. Where the proportion of tin is small, a hard metal is produced capable of much resistance; a larger proportion of tin increases the hardness, but produces brittleness. It is at the same time very elastic, and being adapted for bells, it is hence called *bell-metal.** With a still larger proportion of tin, it forms the alloy used for the mirrors of reflecting telescopes. The alloy of copper with tin can be readily distinguished from that with zinc, on account of the agreeable colour of the latter, which varies with the proportions of the metals. *Pinchbeck* has the least proportion of zinc; common *brass* has more zinc, and the gold-coloured alloy called *Prince's* or *Prince Rupert's metal* contains still more zinc. An alloy of copper, with a very large proportion of zinc, is used for the common white metal buttons.

---

* By mixing lead with bell-metal, a soft alloy is produced called *cock-metal,* which is used in the manufacture of the cheapest descriptions of taps.

The alloys of copper with tin or zinc, being chemical compounds, must consequently be formed in proportions agreeing with their atomic weights. The best proportions for common brass are said to be, two parts by weight of copper to one part of zinc; equal parts form Prince's metal of a beautiful gold colour; 2 of copper to 3 of zinc produce this alloy of a paler yellow, very little malleable; 1 to 2, of a still lighter colour, and not malleable; 2 to 5 produce a yellowish-white, brittle alloy; 1 to 3 very brittle, and nearly white; 4 to 1 produce a very malleable brass, used in watch-work; 6 to 1 an alloy much harder than copper, and inclining to it in colour.

In the compounds of tin with copper, the alloy used for speculums is 11 parts of tin to 4 of copper; 11 to 36 produces bell-metal; 11 to 48 a very hard alloy, used for some culinary vessels; 11 to 84 an alloy used for machinery; 11 to 96 an alloy used for cannon; and 11 to 108 also for cannon, for machinery, and for bronze statues.

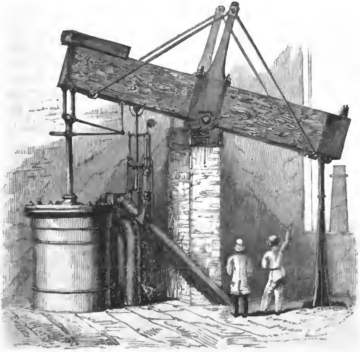
Brass was formerly prepared by cementing granulated copper with calcined calamine, or native carbonate of zinc and charcoal, in a crucible at a bright red heat. The zinc was reduced to the metallic state by means of the charcoal, and combined with the copper into a lump of brass, which collected at the bottom of the crucible. Brass is now manufactured by the direct fusion of its two metallic elements. The zinc is first melted in crucibles, which are prepared by ramming strips of clay into an iron mould, and then properly dried and tempered by heat. The furnace in which the brass is prepared does not greatly differ from that already described in the manufacture of cast steel. Indeed, the two operations closely resemble each other, only in fusing steel a much higher temperature is required.

When the zinc contained in the crucibles in the furnace is properly fused, a quantity of copper is stirred up in it, until an alloy of somewhat difficult fusion is formed. This is taken out and allowed to cool. It is then broken up and melted with an additional quantity of zinc, the heat of the furnace being raised. Each melting takes about eight or nine hours. The crucibles containing the finished brass are lifted out of the furnace through a trap-door in the brick work which covers it over in the workshop above the furnace, and the contents of each

crucible are poured into an iron box, which moulds the brass into a plate about two feet long, and one foot wide, and an inch thick. Before the casting begins, the men shut up the doors and windows, to exclude fresh air, and thus diminish the waste resulting from the partial combustion of the molten brass. The men also tie a handkerchief over the mouth and nostrils, to prevent the inhalation of the fumes. As soon as the cover is taken off the crucible, the oxygen of the air begins to unite with it, producing copious fumes, chiefly of oxide of zinc, or *philosopher's wool*, as it was formerly called, from its white colour and woolly texture. The bluish flame of the burning zinc, and the greenish flame of the burning copper, lighting up the dense white fumes which fill the casting-shop, produce a curious and not unpicturesque effect.

The cast plates are usually rolled into sheets; for which purpose they are cut into ribands of various breadths, but commonly about 6½ inches. These are first passed cold through the cylinders of the brass rolling-press; but the brass soon becomes too hard for lamination. It is therefore softened in an annealing furnace, and again passed through the rolling-press. After cutting off the ragged edges, the sheets are laminated two or more at a time; and if they are to be very thin, as many as eight plates are rolled at once. Before the sheets are sufficiently thin, they often require to be annealed seven or eight times. The annealing furnace has a flat brick floor, and a cylindrical arch, with a fire at each end. In front of the furnace is a large door, which is raised by a chain and counterweight. On the hearth is a kind of railway, composed of two iron bars, on the grooves of which the carriage moves with the sheets of brass placed one above another, but separated by parings, to allow the hot air to circulate among them. In order to economise the heat, two carriages are provided; the one being ready to go in as the other is taken out.

At the Fazeley Street Rolling Mills in Birmingham, where the writer inspected these operations, the moving power of the establishment is a steam engine of 100 horse-power, erected more than sixty years ago by Boulton and Watt. The beam is of massive timber, and its vibrations are accompanied with a loud cracking noise, which would seem to indicate want of strength and stability; but the writer was informed that this noise has always accompanied the working of the beam, and that about thirty years ago an iron beam was got ready to supply the place of the wooden one, which it was thought could not last much longer. And yet this curious and excellent engine still stands, as it were, a monument to the genius of the great improver of the steam engine.



AN ORIGINAL BOULTON AND WATT ENGINE.

Google

MANUFACTURE OF BUTTONS.

AMONG the "toy-trades" of Birmingham, Hutton placed the button manufactory in the foremost rank. "This beautiful ornament," he says, "appears with infinite variation; and though the original date is rather uncertain, yet we well remember the long coats of our grandfathers covered with half a gross of high-tops, and the cloaks of our grandmothers ornamented with a horn button nearly the size of a crown piece, a watch, or a john-apple, curiously wrought, as having passed through the Birmingham press. Though the common round button keeps on with the steady pace of the day, yet we sometimes see the oval, the square and the pea, the concave and the pyramid, start into existence. In some branches of traffic, the wearer calls loudly for new fashions; but in this the fashions tread upon each other, and crowd upon the wearer. The consumption of this article is astonishing, and the value in 1781 was from three-pence to 140 guineas a gross. In 1818 the art of gilding buttons had arrived at such a degree of refinement in Birmingham, that three-pennyworth of gold was made to cover a gross of buttons."

Although at the present day the button manufacture cannot be said to occupy the foremost rank among the occupations of Birmingham, yet it still forms an important feature in the proceedings of that busy town. A visit to a button manufactory reveals a surprising number of curious processes, in which the great manufacturing principle of division of labour is fully carried out. For much of the information contained in the following notice, as well as for the sketches from which the illustrations were made, the writer is indebted to the liberality of Mr. Elliott, who permitted him to inspect his extensive and well-ordered factory.

Probably no article of manufacture is more subject to the caprices of fashion than buttons. Not only do they undergo frequent changes in size and form, but the material is also constantly varying. All the kingdoms of nature are laid under contribution in the manufacture of buttons: metal, horn, shell, glass, mother-of-pearl, paper, coal, jet, precious stones, embroidery and stuffs of all kinds, expressly woven for the purpose, are employed.

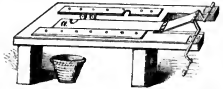
Perhaps the best idea of the button manufacture may be conveyed by first confining our attention chiefly to the processes concerned in the production of a common gilt button. This is made of sheet copper, with a small alloy of zinc, and being laminated in the flatting-mill to the proper thickness, is furnished to the button maker in strips. From these strips *blanks* or circular pieces are cut out, slightly larger than the size of the intended button, by means of fly presses, of which the factory is supplied with a great number and variety. A female sits before one of these presses, and placing one corner of the strip upon a circular die or bed, pulls the handle of the press towards her, when a circular cutter or punch descends and punches out the blank; then moving the handle away from her, the punch is disengaged, and shifting the strip a little on one side to expose a fresh surface, she again brings the punch

down, and forms another blank. All this is done with great rapidity and precision; about thirty blanks per minute, or upwards of twelve gross in an hour, being punched out by one female.

This is generally the first process in the manufacture of a button, whatever its form and variety. A common gilt button is flat, or nearly so, on both sides; but many buttons are convex on the exposed surface, such as those commonly worn by pages or boy-servants. This convexity is produced by placing the blanks one by one in a fly-press, furnished with a concave mould and a convex punch, which, being brought down upon the soft metal, forces it into the mould or bed, and gives it the required shape. The woman holds in one hand a number of blanks, and when one is thus shaped, she dexterously jerks it out with the next blank which is to occupy its place, and with the other hand brings down the punch, and thus the operation is continued with great celerity. Some buttons which are convex in front are closed in behind with another piece of metal, also convex on the outer surface, but less so than the front portion; these are called *shell* buttons; and the two pieces or blanks are afterwards brought together by the action of a die and punch, whereby the edge of the shell is bent over and lapped down upon the bottom in a neat and secure manner, without any kind of soldering. Buttons which are formed with holes instead of a shank, such as metal brace-buttons, are made first by stamping out into blanks; the concavity is then formed with a punch at a fly-press; the holes are next pierced with a punch, and their sharp edges are afterwards rubbed down or *countersunk* with a blunt steel tool, to prevent them from cutting the thread.

After the blanks are cut, the edges are exceedingly sharp, and require to be smoothed and rounded; for which purpose they are rolled between two parallel pieces of steel, about eighteen inches in length, one

Digitized by Google



movable and the other fixed, and both containing corresponding grooves on their corresponding faces. A sliding motion is given to the movable piece *a* by means of the handle. In each grooved piece is a semicircular opening, which, by corresponding once during each revolution of the handle, allows a blank to be dropped into the grooves, which revolving as it proceeds between the two pieces of steel, reaches a hole at *a*, and drops through into a basket beneath. This operation is managed with great quickness by a boy, who places the blanks in the cavity with one hand, and turns the handle with the other.

The blanks are next smoothed or planished on the face, by being placed one by one in a die under a small stamp, and a smart blow given to each by the falling of a polished steel hammer. They are then ready to receive the shanks. The manufacture of these necessary appendages to most buttons forms a distinct branch of trade at Birmingham. They are formed of brass wire, and vary in weight from eight to forty gross in the pound. They are made by a machine, in which a coil of wire is arranged, one end of which gradually advances to a pair of shears, which cut off a short piece; a metal finger then presses against the middle of this piece, and bends it, at the same time forcing it between the jaws of a vice, which compress it so as to form an eye; a small hammer then strikes the two ends, which spreads them out into a flat surface; and lastly it is pushed out of the machine into a small box, and is ready for use. In this way shanks are made by millions in the course of the year.

The shanks are attached to the blanks by women seated at a bench. A blank is taken, and the shank applied to the proper position, and held there by

Digitized by Google

means of a small spring clasp of iron wire, shaped like diminutive sugar-tongs, one limb of which rests on the top of the shank, and the other on the face of the button; a little solder and resin is then applied to the spot where the shank is in contact with the blank. The blanks, thus prepared, are arranged upon an iron plate, to the number of several hundred, and then placed in an oven, the heat of which melts the solder, and on removing the buttons, and allowing them to cool, the shanks are found to be firmly united to the blanks.

If the buttons are to be decorated with a crest, or an inscription, it is now impressed thereon by means of a steel die, containing the device reversed. A die, containing the maker's name reversed, and a hole in the centre for receiving the shank, is firmly fixed upon a solid bench; the other die, containing the device for the face of the button, is attached, with its face down, to a heavy weight, or monkey, moving between two upright posts, and suspended by a cord, which, passing over a pulley, terminates at the other extremity in a stirrup-iron.* It is evident that the workman, by putting his foot into the stirrup-iron and pressing it down, raises the weight with the attached die; and that, by suddenly raising his foot, the weight descends with great force upon the lower die, upon which one of the blanks has been placed, and impresses upon it in relief the device. After

---

* A stamping-press of this kind is represented in No. 18 of this series, page 50.

Google

each blow, the man quickly removes the stamped button, and with the other hand puts another in its place.

The buttons at this stage are very dingy, shabby looking articles. They have now to go through certain processes which give them an ornamental appearance. They are cleansed by being stirred up in a weak solution of nitric acid; then taken out, placed in a perforated earthen dish, and dipped in a stronger acid solution; then washed and dried. If they are to be silvered, they are put into an earthen pan containing a mixture of silver, common salt, cream of tartar, and some other ingredients, and well stirred up for a minute or two, after which they are taken out coated with a silvery white surface.

If the buttons are to be gilt, more care is required in order to economise the gold. If the whole of the button is gilt, it is called an *all-over;* if only the exposed surface or face, it is termed a *top*. The gilding may also be *yellow* or *orange*, according to the mode in which the gold is prepared.

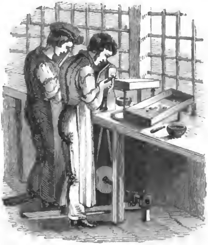
In gilding, the buttons are first pickled in dilute nitric acid, and then thrown into a pan containing a solution of nitrate of mercury, called *quick-water*, the effect of which is to cover the buttons with a thin film of mercury. For tops, the buttons are arranged on a board containing holes for the shanks, and the faces are brushed over with quick-water, whereby a thin film of mercury is deposited.

In the application of the gold, advantage is taken of one of the most astonishing properties of this metal, namely, its divisibility. Five grains of gold are usually allowed for the gilding of 144 one-inch buttons; and in many cases only two and a half grains are employed on the same number of buttons. Gold leaf is usually only the 240,000th of an inch in thickness; a few grains of this leaf are dissolved in about ten times their weight of mercury, gently heated in an iron ladle, and stirred with an iron rod. The amalgam thus formed is then poured into cold water, and afterwards strained through wash-leather, to remove the superfluous mercury; the mass left in the leather is in a semi-fluid state; this is dissolved in dilute nitric acid, and the buttons stirred about in the solution for *all-overs;* or brushed on the face for *tops.*

In this state the buttons present not the slightest appearance of gold; they are of a dull silvery colour, due to the excess of mercury, which has completely dissolved the gold. The gold, however, makes its appearance by driving off the mercury by heat. This *drying off,* as it is called, was formerly done in a sort of shovel, held over an open fire, the buttons being occasionally shaken in a felt cap to recover so much

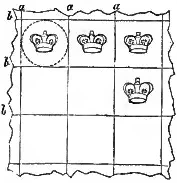
of the mercury as the heat caused to stand in drops on the surface of the buttons. But not only was this method wasteful, but the poisonous fumes of the mercury permanently injured the health of the work-people exposed to them. This led to the construction of a furnace, into which the buttons are placed in a wire cage, and the fumes of the mercury, escaping through the cage, pass into an iron vessel containing water, in which they are condensed. One of the iron cages for holding the buttons is shown on the floor in the engraving; another cage containing the buttons is in the furnace, and the woman is represented turning the handle, to shake the buttons together, so as to expose them successively to the heat.

The buttons come out of the furnace of a dingy gold colour. They receive their beautiful lustre by being burnished at the lathe with blood-stone, as shown in the accompanying engraving.



An act of parliament, passed in the 36th year of the reign of George III. required that for *gilt* buttons five grains of gold should be employed for gilding one gross of buttons; ten grains of gold for those marked *double gilt;* and fifteen for *treble gilt.* Penalties were attached to the putting of false marks on gilt buttons. Another act of parliament, which, though obsolete, the writer believes to be still unrepealed, attaches penalties of from 40*s.* to 5*l.* per dozen, to any person who shall cover button moulds with the same kind of cloth as the coat. This law was intended to uphold the gilt button manufacture, which has suffered greatly from the introduction of various forms of buttons, some of which may be briefly noticed.

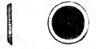
The most formidable rival of the gilt button is the *florentine* and the *silk* button. Various patents have been taken out from time to time for improvements in this branch of the button manufacture. In one of Elliott's patents the fabric for covering the buttons is expressly woven for the purpose, and it contains patterns or ornamental designs at such distances apart as to be suitable for being cut into circular portions, each for the covering of a button. Care is taken that the ornamental figures be only so far apart that, in cutting up the fabric into discs for covering the buttons, there should be as little waste as possible; and, in order to facilitate the cutting out of the fabric truly, the discs are woven in squares of such sizes that the tool used in stamping out the circular surface has the figure correctly in the centre. These squares are formed by warp and weft threads of a different colour from the rest of the fabric, and arranged at such distances as to allow of the required circle being cut. The warp threads are shown at *a a a*, and the weft threads at *b b b*. In this way the fabric is divided into a series of squares, each having a device, or ornamental figure, such as a crown, a coronet, letters of the alphabet, such as V. R., or other device, coming within the boundary line of the button. The fabrics used for these buttons are a satin ground, with the ornamental central figure of any fibre. The ground may also be of satinet, twill,



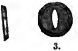
or florentine, barathe, velour, tabby, broglio, or satin and tabby.

The contrivances employed in the manufacture of a florentine button are very ingenious. In the first place, the various parts of the button are cut out at the fly-press. These are, a metal shell, shown in (1), in front and side-ways; a metal collet (2), containing an oblong hole for the shank of the button; a circular piece of silk, or other woven covering for the button (3); the padding which lies under the collet (2), round which is wound, at right angles to the length of the oblong hole of the collet, a thread (4), which acts as a flexible shank to the button. This padding consists of several layers of soft paper, having a piece of silk, or other fabric similar to the covering of the button, and forming the back surface which comes in contact with the face of the garment to which the button is attached. The various discs, consisting of the silk covering, a disc of paper to prevent the metal shell from cutting the silk, and the shell, are shown in (5), as they are placed upon the die, or mould, shown in section in (6), and which serves to bring the parts properly together, previous to their undergoing the final pressure by which the button is completed.

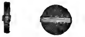
1.



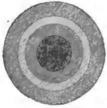
2.



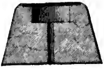
3.



5.

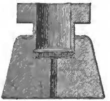


6.

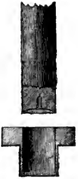


In forming a button, the circular piece of silk (3), or other fabric, is first placed on the face of the die, or mould, (6); a metal shell (1), is then placed on the silk covering, and the two together are pressed down to the bottom of the die by means of a punch, which almost exactly fits the hollow of the die. The punch is then removed, and a hollow tool (7) forced into the die, by which the edges of the silk are forced towards the centre of the die, and consequently overlap the edges of the shell. The collet (2), containing the padding, is then dropped into the mould through a hollow tool (8), the collet being uppermost. A punch is next forced down with considerable pressure through the hollow tool, by which means the padding and the edges of the outer covering of the button are all forced into the shell, which retains them sufficiently secure until the button undergoes the final pressure for completing it. The button thus far produced, is removed from the die (6, 7) by a wire passed up through a channel made for the purpose.

7.

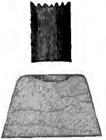


8.



The final pressure is given to the button by a punch (9) with a plain face. The button is put into the mould (9), with the collet downwards, and pressed into the die by the punch, the workman holding a piece of tissue paper between the button and the punch, to prevent injury to the face of the button.

9.



The flexible shank is not required to protrude; it is attached to the garment by passing the needle under the threads (4), in the direction of the oblong hole of the collet (2).

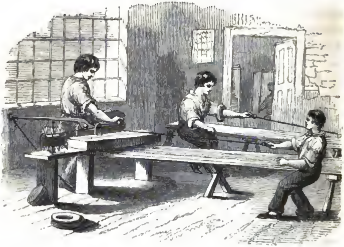
In one of Mr. Elliott's improvements the punch and upper die (7) and (8) are so constructed and worked that the two together act the part of the proper die for causing the button to be pressed into shape, without requiring that the parts of the button, after being brought together in the die, should be taken out and placed in another die to be acted on by another punch; so that, in addition to covering the front shell and bringing the parts of a button together, they also press the button into shape. Even so slight an improvement as this has been made the subject of a patent, for, by diminishing the number of processes, time and labour are economised, and the manufacturer is thus able to offer his articles at a slightly reduced rate, which gives him a preference in the market. It would be worth the reader's while to dissect one of these covered buttons, and while reading the above description, and comparing it with the various parts which he is separating, he may well be surprised that so much skill, ingenuity, machinery, capital, and the labour of thousands, are employed in the production of articles which he can purchase at less than a penny each.

MANUFACTURE OF PINS.

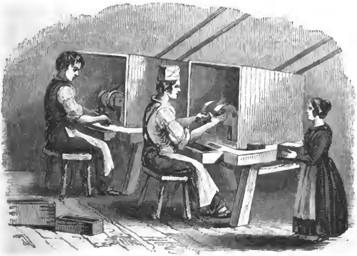
THE manufacture of pins furnishes another remarkable instance of the division of labour. Fourteen persons are engaged in the production of a pin, to say nothing of the previous preparation of the wire by the wire-drawer; and yet a paper of pins, containing 250 well-finished articles, can be bought for fivepence.

The wire obtained by the pin-maker from the wire-drawer is in a very soft state, and covered with a scurf or oxidation, in consequence of its having been heated to redness in annealing. To make this wire sufficiently clean, hard, and of the gauge or size required by the pin-maker, it is pickled in dilute sulphuric acid, well washed, beaten, and dried. It is then wound upon a reel or barrel, and the loose end being filed is passed through a draw-plate, and attached to an iron barrel, which is made to revolve by means of a horizontal handle. In this way the wire is passed through the draw-plate and wound upon the barrel, by which operation it is reduced to the proper size, and rendered hard and bright.

The wire is now to be straightened and cut into lengths, which is done by pulling the wire with pincers from the barrel through another draw-plate, and running it out upon a low wooden bench or trough to the length of twenty feet; that piece is then cut off, and the boy returns and draws out an equal portion. In this way the wire is straightened and cut into lengths of twenty feet. These lengths are next cut with shears worked by the foot into lengths of rather more than six pins. Each of these lengths is then pointed at each end at a machine called a *mill*, consisting of a circular single-cut file and a fine grit-stone. The grinder takes from fifty to eighty of the pin-wires in his hands, and spreading them out in one plane, applies them first to the circular file, which points them, and then to the stone, which polishes them. It is necessary to give a



rotatory motion to the wires all the time; and this is done by a skilful motion of the thumb and fingers.



This employment, like that of needle and fork-grinding, is a most pernicious one unless proper precautions are taken; the fine brass dust inhaled into the lungs produces consumption, and getting into the eyes produces blindness. The general introduction of the ventilating apparatus, described in No. 18 of this series, page 55, has happily removed all serious objections to this employment.

From the ends of each of the wires, thus pointed, lengths are cut off sufficient to make two pins. The intermediate portions are returned to the pointer, who points the two extremities as before: two lengths are again cut off from each wire; and the intermediate portions being again pointed, furnish each two pins by being divided in the centre.

The wire for the pin-heads is drawn out much finer than that employed for the pins, and is also much softer. It is coiled into a compact spiral round a wire of the size of the pins; the central wire is then withdrawn, and two or two-and-a-half turns of the spiral cut off for each head. The wire is coiled by means of a small lathe or Jersey spinning-wheel, to the spindle of which is fastened the *mould* or wire, about forty inches in length and of the thickness of the pin: the heading wire is fastened to a small projection at the end of the spindle; and both the mould and the heading-wire are passed through two small loops in a wooden handle which the workwoman holds in her left hand to regulate the winding, while her right hand is employed to turn the wheel. By this means a rotatory motion is communicated from the spindle to the mould-wire, and the heading-wire, being held at right angles to it, is coiled closely round it almost from end to end. The coil is then slipped off the mould and another formed as before.

The cutting up of the coil into heads is performed by a sort of guillotine. A sharp chisel, fixed in a vertical plane in a wooden frame, is held down by a spring: a lever, proceeding from the upper part of the chisel, becomes engaged for a moment in one of the cogs of a wheel rotating near it: this depresses the lever and raises the chisel; then the lever immediately escaping from the cog, the spring forces the chisel down; but no sooner is the chisel forced down than another cog comes into action, depresses the lever, and raises the chisel: in this way, the wheel, being furnished with a number of cogs, gives to the chisel a rapid chopping motion. In the meantime a number of the spirals being placed upon a horizontal board, are slowly advanced under the edge of the chisel in so graduated a manner, that two turns of each spiral are cut off at each descent of the chisel.

The method of putting on the heads is as follows. A boy or girl has a number of the heads in his apron, and a number of the headless pins by his side: taking up a number of the latter between his fingers, he plunges them into the heads, and moves them through with a sort of threading motion: the wires in this way catch up each a head; one wire may catch up two; another three; a third, none at all; in the latter case he passes this wire into the heads again: then quickly pulling off the superfluous heads, he presses his foot upon a treadle, which, acting upon a lever, raises a weighted square bar of iron; he then places the pins points downwards, one at a time, into a little steel die, and suddenly removing his foot from the treadle, the heavy bar descends, strikes the top of the pin, *moulds* and fastens the head, and leaves the top smooth and round. A small spring below the die prevents the pin from passing deeper into the die than two-thirds of its length, except when the heavy hammer descends and drives it home; as soon, therefore, as the blow is struck, and the man again presses the treadle, this little spring comes into operation and raises the pin one-third out of the die, so that the man can instantly remove it and insert another pin in its place. An expert workman will head 1,500 pins per hour, or from 12,000 to 15,000 per day.

In this state the pins are very dingy and dirty-looking, and such as no female would like to use, although as pins they are perfect. They are cleaned by boiling for half-an-hour in sour beer, wine lees, or a solution of tartar; after which they are washed. Then comes the *whitening*, or tinning process. A stratum of about six pounds of pins is put into a copper pan, then a stratum of seven or eight pounds of grain-tin, and so on, alternately, until the vessel is filled. Water is then poured into the pan, and it is set upon the fire: as soon as the water gets hot, its surface is sprinkled with four ounces of cream of tartar, after which it is allowed to boil for an hour. This operation is repeated once or twice, the pins between each boiling being washed in cold water.

After the tinning, the pins are polished in a leather sack filled with bran, which is agitated to and fro by two men. The bran is separated by winnowing, and the pins are collected in bowls for papering.

The paper into which the pins are stuck is crimped by means of crimping-irons; the folds are then gathered together and placed, with a small portion projecting between the jaws of an iron vice which close with a slight spring: grooves are channelled across the jaws of the vice to serve as a guide to the paperer, generally a girl, who sits before the vice with her lap full of pins. Passing a common horn comb into the heap, she catches up a number of pins, the heads of which rest between the teeth of the comb, and taking them out between her fingers and thumb, presents the points to the paper along the grooves of the vice. She then presses them in with a metal guard on the left-hand; and when one row is filled in, she pulls open the vice, takes out the paper, gathers together the next row of folds, places them in the vice; then collects another comb-full of pins; and thrusts them into the paper as before. All this is done with surprising rapidity; but, occasionally, the girl forces a pin against the opposite jaw of the vice instead of clean through the paper, and bends it; this is taken out and thrown aside as waste. The waste in the whole manufacture is calculated at one-thirteenth of the whole number produced.

The *daily* consumption of pins for this country alone has been calculated at upwards of fifteen millions! The question may well be asked, "What becomes of all the lost pins?" for there is no doubt that this number is in some way or other used, lost, or otherwise unaccounted for every day; and there is a greater loss of metal in this apparently insignificant article than in any other branch of manufacture.

Attempts have been made at various times to produce pins entirely or chiefly by machinery. One of the most complete of these machines is Wright's, which was patented in 1824. The following outline will convey some idea of its structure;—"The rotation of a principal shaft, mounted with several cams, gives motion to various sliders, levers, and wheels, which work the different parts. A slider pushes pincers forwards, which draw wire from a wheel at every rotation of the shaft, and advance such a length of wire as will produce one pin. A die cuts off the said length of wire by the descent of its upper chap; the chap then opens a carrier, which takes the pin to the pointing apparatus. Here it is received by a holder, which turns round, while a bevel-edged file-wheel rapidly revolves and tapers the end of the wire to a point. The pin is now conducted by a second carrier to a finer file-wheel in order to finish the point by a second grinding. A third carrier then transfers the pin to the first heading-die, and by the advance of a steel punch, the end of the pin-wire is forced into a recess, whereby the head is partially swelled out. A fourth carrier removes the pin to a second die, where the heading is perfected. When the heading-bar retires, a forked lever draws the finished pin from the die, and drops it into a receptacle below."

It is stated that the chief objection to the raising of the heads by strong mechanical compression upon the pins, is the necessity of having a soft wire; so that however beautiful the pins may appear, they are not sufficiently firm for many purposes to which pins are applied.

MANUFACTURE OF TIN-PLATE.

One of the most important applications of tin is for coating other metals, especially iron, in order to preserve it from rusting and thereby staining other substances placed in contact with it. Many articles, such as bridle-bits, common stirrups, small nails, &c. are now manufactured at a cheaper rate than formerly, by first making them of cast-iron, and then covering them with a coating of tin. Saucepans and large pots of cast-iron, permanently tinned on their inner surface, are now in common use.

But perhaps the largest demand for tin is in the manufacture of *tin-plate*, or *white iron*,—that is, thin sheet-iron covered on both sides with an equable layer of tin,—of which coffee-pots, saucepans, tea-kettles, and a variety of culinary articles are manufactured by the tin-man or tin-plate worker. The sheet-iron intended for this manufacture is refined with charcoal instead of coke, and is rolled out to various degrees of thinness, and cut by shears into rectangles of different sizes. The sheets, thus prepared, are arranged in heaps of 225, which number is technically called a *box*.

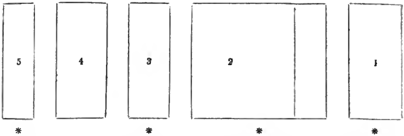
The first step towards tinning is to clean the surface of the sheet-iron of oxide and impurity, which would prevent the tin from forming an alloy with the iron. A workman, called the *scaler*, bends the plates across the middle, thus, for the purpose of keeping the surfaces of different plates distinct and separate, and then places them in a trough containing a dilute solution of hydrochloric acid. They are taken out after four or five minutes, and placed upon the floor in a row, and then, by means of an iron rod put under them, are lifted up and conveyed to a furnace, where they are heated red-hot. The heat causes a thick scale of rust or oxide to fall off. The plates are then taken

out and placed on a floor to cool; after which they are made straight and smooth by being beaten on a cast-iron block. If the plates have been properly *scaled,* they have a mottled blue-and-white appearance, something like marbled paper. The plates are further smoothed by being passed between a pair of hard polished rollers screwed very close upon one another. This *cold rolling* gives a high degree of smoothness and elasticity to the plates.

The plates are next put into a mixture of bran and water, made acid by keeping; they are immersed one at a time, to ensure their being completely wetted; they are left for about six hours standing on their edges, then turned or inverted, and left for another six hours. They are then taken out and removed to a pickle of dilute sulphuric acid contained in a leaden vessel, divided by partitions of lead, each compartment capable of holding one box of plates, being called a *hole.* The effect of the acid is to remove all black spots, and to make the plates perfectly bright; but judgment is required not to carry the pickling too far, otherwise the plates will become stained, or *blistered,* as the workmen call it. Both this and the former process with bran-water may be assisted by raising the temperature to 90° or 100°, for which purpose the troughs are placed over heated flues. The plates are now removed to clean water, and scoured with hemp and sand; and it is a remarkable circumstance, that after being thus well washed, the plates may be kept immersed in water during many months without losing their bright appearance or acquiring any rust.

All these processes are preparatory to actual tinning. The tin is melted in a cast-iron vessel heated by a fire beneath, while the flue goes entirely round it. About five hundredweight of block and grain tin, in nearly equal proportions, are melted in this vessel, and a quantity of tallow sufficient to cover the molten metal to the depth of four inches is added.

This prevents the oxygen of the atmosphere from acting on the tin, and the workmen imagine that it also makes the iron plates take the tin better. Another pot, placed beside the tin pot, is filled with grease only, into which the prepared plates are put previous to tinning. They are taken out one by one and plunged into the tin in a vertical position to the number of two or three hundred, and they are allowed to remain an hour or two in the tin, which is kept as hot as possible without setting fire to the grease on the surface. The plates are then taken out with tongs, and placed upon an iron rack or grating: a considerable portion of superfluous tin drains from them, but still more is got rid of by a process called *washing*, which is rather complicated. The wash-man prepares an iron pot nearly full of the best grain-tin melted; this is called the *wash-pot:* there is also another pot of clean melted tallow, called the *grease-pot:* a third pot, containing only a grating at the bottom to receive the plates when taken out of the grease-pot; this is called the *pan:* there is also a fourth, called the *list-pot*, containing only a small quantity of melted tin. This arrangement will be better understood from the following diagram showing the arrangement of the vessels:—



No. 1 represents the tin pot in which the plates were first tinned. No. 2 the *wash-pot*, divided into two portions by a partition to prevent the dross from lodging in that part of the vessel where the last dip is given to the plates. No. 3 is the *grease-pot.* No. 4 the *pan,* with a grated bottom. No. 5 the *list-pot.* The building in which these pots are fixed is called the *stow,* and the plates are worked from the right-hand to the left of the stow. The asterisks show where the work-people stand.

The wash-man begins his operations by putting the plates already tinned by the first process into the wash-pot, and the heat of the large body of wash-tin contained in it soon melts all the loose tin on the surface of the plates, and gradually renders the whole mass so foul, that after sixty or seventy boxes of plate have been washed in the grain-tin, the weight of a block (300 cwt.) of it is transferred to the tin pot No. 1, and replaced by a fresh block of grain-tin in No. 2.

The plates being taken out of the wash-pot by means of tongs held in the left hand of the workman, he brushes the plate on both sides with a peculiar kind of hempen brush, then dips it for a moment into the hot tin, and immediately plunges it into the grease-pot No. 3. This is done with such rapidity, that although only 3*d.* be paid for brushing and tin-washing 225 plates, yet a good workman can earn 6*s.* 3*d.* in twelve hours by putting 25 boxes, or 5,625 plates, out of hand; and yet each plate must be taken up, brushed on both sides, and dipped twice into the pot of melted tin. The final tin dip is for the purpose of removing the marks of the brush, and giving a uniformly bright surface to the plate. The use of the grease-pot is to remove the superfluous metal from the plates; but this requires much care, because, as the tin is in a soft state when immersed in the grease, too much or too little may be removed: if too much tin is removed the plates lose their silvery lustre; if too little, the manufacturer suffers loss, and the plates are disfigured by streaks of tin. The temperature of the grease-pot also requires attention, because, as a thick plate retains more heat than a thin one after being

Digitized by Google

lifted out of the wash-pot, it requires a proportionably cooler grease-pot. The grease-pot has pins fixed within it to keep the plates asunder, and whenever the workman has transferred five plates to it, a boy lifts the first out into the cold pan adjoining, marked No. 4; as soon as the workman transfers a sixth plate the boy removes the second, and so on. The plates are left in No. 4 until they are cold enough to handle.

As the plates are placed vertically, both in the melted tin and also in the grease-pot, there is always a *list*, or salvage of tin on the lower edge of each plate after it becomes cold: this is removed by dipping the lower edge of each plate into the list-pot, marked No. 5, which contains melted tin, to the depth of about a quarter of an inch. When the list is melted, the boy takes out the plate and gives it a smart blow with a thin stick, which detaches the superfluous metal, leaving a faint mark in its place, which may be noticed on every tin plate.

The plates are cleansed from grease by being put while warm into bins of dry bran, with which they are rubbed until quite clean. They are then packed up in boxes, each containing a certain number of plates, according to their quality, which is distinguished by certain marks attached to the boxes.

MANUFACTURE OF SHOT AND LEAD PIPES.

THE method of making lead shot is similar in some respects to the natural process by which rain is converted into hail: leaden rain falling through the air from a considerable elevation becomes cooled and solidified into leaden hail. This method originated with a plumber of Bristol named Watts, who in 1782 is said to have dreamed that he was out in a shower of rain, and that instead of the sky raining water it rained lead, and to his surprise the drops of lead were perfectly spherical. He determined to try the experiment, and accordingly poured some melted lead from the tower of St. Mary Redcliffe church, into some water below; the plan succeeded, and he sold his invention for a large sum of money.

For the carrying out of this invention shot-towers and shot-wells have been constructed. At the top of the fall melted lead is poured into a colander, and the drops are received into a vessel of water below. In large establishments from two to three tons are melted at once. The surface of the lead becomes covered with a spongy crust of oxide, called *cream*, which is used to coat over the bottom of the colander, to prevent the lead from running too rapidly through the holes, thereby forming oblong spheroids instead of spheres. The colanders are hollow hemispheres of sheet iron, about ten inches in diameter. The holes differ in different colanders, according to the size of the shot. For shot known as No. 0, the holes are $\frac{1}{50}$th of an inch in diameter: for No. 1 the holes are $\frac{1}{58}$th in.; for No. 2, $\frac{1}{66}$th; for No. 3, $\frac{1}{72}$nd; for No. 4, $\frac{1}{80}$th. From No. 5 to No. 9 the diameter decreases by regular gradations, the latter being only $\frac{1}{360}$th of an inch. These dimensions are, of course, very much smaller than those of the shot produced; for the lead passes through the holes of each colander in fine threads, which collect into globules of the size of the shot on the under surface of the colander.

When the shot are taken out of the water they are dried on iron plates heated by steam. The imperfect shot are then separated by a curious process. A slab of polished iron is tilted at a certain angle, and the shot are strewed along the upper part of the inclined plane thus formed. The perfect shot proceed rapidly in straight lines, and fall with a bound into a bin placed to receive them, about a foot away from the bottom of the slab. The misshapen shot, on the contrary, travel with a slower zigzag motion, and fall without any bound into a bin placed immediately at the end of the incline. By this simple contrivance the good and the bad shot are effectually separated.

The shot are now of a dead silvery-white colour. They are polished and made dark in an iron barrel containing a small quantity of powdered plumbago, and made to revolve rapidly. They are then tied up in canvass bags containing 28 lbs. each, and are ready for sale.

Lead piping is made by a process exactly similar to that of wire-drawing. A plug of lead from two to four feet long, and of considerable thickness, is cast with a bore in the centre of the exact size of the intended pipe. The plug is then put upon a long steel mandrel of the size of the bore, and passed between rollers with grooves of different sizes according to the external diameter required, or drawn through metal wortles or collars of different sizes, each succeeding hole being less than the former, until the pipe is extended to the length and thickness required. By this method the lead is compressed and rendered more durable. A bright smooth surface is given to the pipe by passing it once or twice through a cutting die, which shaves off a thin film of the metal. An endless chain passing round two wheels or rollers, set in motion by connexion with steam-power, is used to drag the pipe through the holes of the collars.

R. CLAY, PRINTER, BREAD STREET HILL.

THE MANUFACTURE OF POTTERY, PORCELAIN, AND ENCAUSTIC TILES.

HISTORICAL NOTICE.

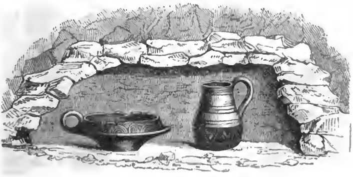
In almost every part of the habitable globe *clay* forms a portion of the soil, while in many places it exists in large quantities, so as to form a natural basin under the surface retaining the moisture of the earth and leading to the formation of marshes and fens. We cannot suppose that man, even in a savage state, could fail to observe this power of clay to retain water: every pool at his feet remaining stagnant, instead of sinking into the earth, would remind him of the fact. At the same time his own wants and necessities would constantly lead him to seek for something which would serve for a drinking-vessel, and which could be fabricated with no other help than the human hand. It is not to be wondered at, therefore, that the art of making, from this clay, the most rudimentary forms of pottery should belong to all nations and to the earliest times.

Clay in all its varieties is a silicate of alumina, more or less mixed with other matters, according to the nature of the rocks from which it was originally derived; for this substance is slowly but constantly produced by the action of air and water on certain rocks which gradually crumble away under their influence, and are carried by rains and rivers to form the soil of the valleys below. The greater or less purity of the clay, as employed in pottery and porcelain, gives rise to many of those varieties in the character of the several manufactures which serve to distinguish one town, or district, or country from another. But in every article produced, from the coarsest specimen of earthenware to the most delicate porcelain cup, the two ingredients, silica and alumina, must necessarily be present, although impurities, such as iron, lime, potash, &c., largely accompany them in the case of the coarser vessels.

The fabrication of pottery in the earliest times was of a very simple description, and the articles being merely *sun-baked,* were for the most part fragile. Those for domestic use had probably to be renewed every season, but those which took the form of bricks and slabs had a marvellous length of existence. The sun-dried bricks of Egypt, Assyria, and Babylon have been preserved to this day, and are found to have straw mixed with the clay, in accordance with the Scripture account of the making of bricks in Egypt. At what period the method of making pottery more durable by the action of fire was discovered, is not known, but this also is of great antiquity, since remains of baked earthenware are found in Egyptian tombs of the first dynasties, and some of the oldest bricks and tablets of Assyria and Babylon bear marks of having passed through the fire, while articles of a somewhat later date are also covered with an opaque enamel. By means of the inscriptions on these ancient bricks much information respecting the names of kings, and the sites of cities, has been transmitted to a later age. Thus this simple material and primitive manufacture have assumed historical importance, and have rendered the same kind of service in reading the history of remote ages that printing has done for the more enlightened. In the palace of Sennacherib, the traveller Layard discovered a whole library of clay books, consisting of histories, vocabularies, deeds, &c., in the form of tablets, cylinders, and hexagonal prisms of *terra cotta.*

The word *pottery* is derived from *potum*, the Lower Latin word for a drinking vessel, and the earliest destination of clay was doubtless for making bricks, earthen vessels, &c., for the common purposes of domestic use. But there was a higher purpose to which they were likewise devoted, and which has been the means of preserving to us many interesting relics of the past: we allude to the religious use of earthen vessels of various kinds, and the custom of placing them in tombs and barrows along with the remains of the deceased.

Funeral vases in great variety, from rude and simple forms to those that are graceful and elaborate, have been found in the tombs of most ancient nations. An incalculable number have been met with in the burying-places of the ancient Britons, Scandinavians, Germans, French, Celts, Etruscans, Greeks, and Romans; and this practice has been also traced in America, among the ancient Peruvians, Chilians, and Mexicans. Earthen vessels in such situations remain almost unalterable, while weapons and even medals are corroded, and in the course of long ages are either rendered shapeless or destroyed. The following woodcut represents the interior of one of the tumuli so common in the north of Germany, and the sort of vessels that are found therein. These latter



INTERIOR OF A TUMULUS NEAR RADEBERG.

were doubtless the depositories of the ashes of the dead, as no skeleton or bones were found in the tomb. In many cases, however, the skeletons still remain, with vases placed at the feet, and sometimes at the head also, or hanging on pegs from the sides of the tomb.

SEPULCHRAL URN,
FOUND NEAR WILSFORD, WILTS.

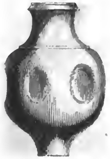
DECORATED URN, FOUND AT
COLNEY IN NORFOLK.

ROMAN AMPHORA,
DUG UP NEAR LONDON BRIDGE.

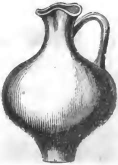
SPECIMEN OF
EGYPTIAN UNGLAZED POTTERY.

In the specimens thus widely distributed over the earth there are distinctive features which render the potteries valuable in their simplest as well as in their more elaborate forms. The simple and rudely-formed British urns are easily distinguishable from the more carefully finished works of the Roman conquerors of these islands.

The potteries of Egypt, again, are not to be confounded with those of other nations. The potteries of India are characterized by their red and black, as those of North America are by their black and white material, the latter being interspersed with the fragments of bivalve shells. Widely different, again, are the ancient potteries of France, of which the following, of a fine ash-grey colour, were found near Dieppe, the first having curious indentations in its sides, as if to accommodate small urns which were found near it, the second being of a more elegant shape, and supposed to be Gallo-Roman of the age of the Antonines.



URN FOUND NEAR DIEPPE.



VASE FOUND NEAR DIEPPE.

The beauty of the forms of Greek vases is well known, for they have been constantly repeated in various kinds of earthenware in modern times. Greek and Etrurian pottery indeed, displays such delicacy and perfection, that it is viewed with astonishment by modern workmen, who know the difficulty of producing such results. At the manufactory at Sèvres, some of these specimens have been given to the cleverest artificers, as problems in workmanship which they were to solve, not by explanations, but in practice. The methods employed in working out these problems are given in Brongniart's admirable work on Potteries. (*Traité des Arts Céramiques*, &c. 1844.)

BLACK VASE
WITH A ZONE OF WHITE
IN THE MIDDLE.

GREEK VASE.

PURSE-SHAPED VASE,
RED AND BLACK.

RICHLY ORNAMENTED
COVERED VASE.

YELLOW VASE,
WITH ORNAMENTS IN BLACK AND RED.

GRECIAN VASES.

Digitized by Google

The art of making decorated pottery was lost for a time in Europe after the overthrow of the Western Empire. But it began to revive under the auspices of the Mohammedan invaders of Spain, who employed ornamental pottery in the buildings of Seville, Toledo, Granada, and the Alhambra. The Spaniards learned their art, and a manufacture arose, the productions of which are called *Hispano-Arabic* pottery, and are characterised by a white or coloured opaque enamel on which elaborate designs and inscriptions are executed in colours. It resembles the Italian *majolica*, and was long confounded with it. The latter, however, is said to derive its origin and name from the island of Majorca, whence a number of plates of Moorish pottery appear to have been brought, about the year 1115, and inserted as religious trophies in the walls of the churches of Pisa. It was not until the fourteenth century, however, that these ancient specimens were imitated, and the celebrated ware produced which was afterwards so extensively manufactured as *majolica*. In 1451 this manufacture flourished in Pesaro, the birthplace of Luca della Robbia, who is regarded by some persons as the inventor of the ware. This artist produced figures, architectural subjects, &c. in *terra cotta*, and covered them with enamel of a dazzling whiteness and surprising durability. The manufacture of majolica flourished for nearly two centuries, and it was said that Raffaelle himself furnished designs for it, hence the name of *Raffaelle ware;* but as the finest specimens were not produced until 1540, when Raffaelle had been dead twenty years, it is probable that his pupils furnished designs, and possibly made use of some of his drawings in composing them. But majolica ware was not always thus artistically adorned: there were common articles of domestic use, either plain or with grotesque figures in relief, plates, vases, flasks, pilgrims' bottles, cups, birds, tiles for walls and floors, &c. There were also saucers or plates called *amatorii*, containing the portrait and name of a lady: these were filled with fruit and sweetmeats, and offered as appropriate gifts. The coarser specimens of majolica were known as *mezza-majolica*, the finer, though inappropriately, as *porcelana*. Majolica was introduced into Germany in 1507, but had no long existence in that country. In France it was patronised by Catherine de Medici, and her kinsman, Gonzaga; and, under the name of *faience* (said to be derived from a small town of that name in the department of Var) it flourished for a considerable period. Another kind of ware for which France became celebrated was called *Palissy ware*, from Bernard Palissy, the inventor of it, whose pursuit of knowledge under difficulties forms a well-known tale of considerable interest. He did not attain to the purity and elegance of the true majolica ware, but produced a kind of rustic pottery which became fashionable, and was highly adorned with objects in relief, most of which were accurately copied from nature.

In the sixteenth century, Holland was celebrated for a ware called *Delft* (from the place of its manufacture), which was distinguished by its good colour and fine enamel, but was disfigured by the representation of strange and monstrous animals, after the Japanese models, Holland having an exclusive trade with Japan. This delft ware became so generally distributed that it was called the "parent of pottery." Several towns of Germany also became famous for enamelled wares, which were distinguished for their fine green glaze and elaborate forms. Large enamelled tiles for covering stoves were extensively made at Nuremberg.

The first manufacture of fine earthenware in England is said to have been that of Stratford-le-Bow, in the reign of Elizabeth. The pottery of that period is nearly as hard as fine *stone ware*, and is of a dingy white with ornaments in relief. The Staffordshire potteries came into notice in the same reign, and produced among their earliest specimens butter-pots of native brick-earth, glazed with powdered lead ore, which was dusted on while the ware was in a green state; there were also drinking-cups with two, and even three handles. There was also a manufactory of earthenware at Fulham, specimens of which are still preserved as *Fulham ware.* During the reign of Anne, and of George I. *agate-ware,* and *tortoise-shell ware* became fashionable. This was made of sand and pipe-clay, coloured with oxide of copper and manganese, and became the foundation of that description of ware, which in the hands of Wedgwood became so celebrated as *Queen's ware.* Josiah Wedgwood, the son of a potter at Burslem in Staffordshire, with few educational advantages, and under many and serious discouragements, succeeded, from the middle to the close of the last century, in raising the character of the pottery of this country to an eminence which enabled it to compete successfully with the finest productions of foreign nations. Previously to his time, Britain obtained its porcelain from China, and the great bulk of its earthenware from France, Germany, and Holland. But his beautiful inventions won the favour of royal and noble personages, and became extensively patronised. His labours were of an extraordinary kind, and his discoveries were due, not to happy accidents, but to patient investigation and the most untiring industry. His success becomes all the more honourable when we find that he overcame the serious disadvantage of a neglected education, and disciplined his own mind, ere he entered on investigations that were purely scientific; and when wealth poured in upon him, it did not unfit him for duty: on the contrary, it became the means of greatly enlarging his sphere of usefulness, for he employed it in the extension of knowledge and in the alleviation of misery among his fellow-creatures. His charities, public and private, were munificent, and at the same time judicious;

so that Wedgwood deserves to be respected, not merely as the most successful potter, but as one of the most enlightened men of his day. His principal inventions were a beautiful and useful table ware called by royal command *Queen's ware;* a *terra cotta* which could be made to resemble porphyry, granite, &c.; *basalts,* or black ware, a kind of porcelainous biscuit having nearly the same properties as natural stone, and striking sparks like a flint; a *white porcelain biscuit* of a smooth wax-like appearance, but with qualities very similar to the basalts; *bamboo,* or cane-coloured biscuit of the same nature; and *jasper,* a white porcelainous biscuit of exquisite delicacy and beauty, having properties that especially fit it for the production of cameos, portraits, &c., since the ground can be made of any colour, while the raised figures are of the purest white; also a *porcelain biscuit* little inferior to agate in hardness, and much used for mortars in the laboratories of chemists. These important manufactures were carried on in a village in Staffordshire built by Wedgwood himself, and dignified by the name of Etruria.

The success which attended Wedgwood's processes, was doubtless a great cause why the manufacture of porcelain (properly so called) did not advance in England, for many of his wares were so beautiful as almost to supersede the necessity for anything of a higher description. Nevertheless, the discovery in 1768 of certain mineral substances in Cornwall, similar in their properties to the porcelain earths of China, led to the production of a superior quality of china to any that had been previously made in England. For the cause just stated, however, this china was not in great demand. From the time of Wedgwood to the present day, the continued industry and growing intelligence of manufacturers have carried forward various improvements both in earthenware and porcelain, and have brought these productions to great perfection. Porcelain is now made in the Staffordshire potteries, at Derby, at Coalport, near Colebrook Dale, in Shropshire, in the city of Worcester, and at Swinton, near Rotherham, in Yorkshire.

WEDGWOOD'S FACTORY AT ETRURIA, IN STAFFORDSHIRE.

Stone-ware thus improved by Wedgwood, and which was also undergoing improvements on the Continent, gradually led the way to the manufacture of the true porcelain, specimens of which from China, Japan, and Persia, had found their way at different times into European countries and excited the emulation of the inhabitants. The Chinese place the invention of porcelain at an incredibly early period in their history; but it appears to be a fact that an inferior kind of porcelain was dug from the ruins of a palace which was built about 163 years before the Christian era. But it was not until 400 or 500 years after the Christian era that their porcelain was made of fine materials. But even this date makes it apparent that the porcelain of China was made more than 1,200 years earlier than our European porcelain. Numerous and splendid collections were brought from China by the Portuguese, who were struck with the resemblance of the material to cowrie shells or "porcellana," and imagined the ware to be made of such shells or of a composition resembling them. Hence, apparently, the name of *porcelain.* They also called it from its ringing sound *China metal.* About the middle of the seventeenth century the taste for collecting China amounted to a passion. *Blue* and *white,* and *pale buff porcelain* was brought from Nankin; *sea green,* and *crackle porcelain,* from King-te-tching; *snake porcelain,* and *egg-shell porcelain,* from both China and Japan. Two centuries of effort were insufficient to produce any European copies of these beautiful materials, until at length an accidental circumstance brought to light the very substance, the want of which had been the cause of failure.

Jean Frederic Böttger was an apothecary's assistant at Berlin, who afterwards took up his residence at Dresden, and established a factory at Meissen under royal patronage. He had laboured long and diligently to find the secret of making porcelain, but could only succeed in producing a kind of ware, hard and ringing like other ware, smooth and fine in texture like porcelain, but of a red opaque colour. Nevertheless, it soon got into great demand in Saxony. About the year 1711, his works began to produce a beautiful white porcelain, the origin of which was as follows:—It happened that a rich forge-master was travelling on horseback, through Aue, near Schneeburg, and observed that his horse's feet sank deep in a soft and white-looking earth, which impeded his progress. It immediately struck the merchant that this white powder might be made an article of trade, by introducing it instead of the flour of wheat for head powder, which was then very much in fashion. He accordingly collected some, and having found it to answer his expectations, he commenced the manufacture, and sold his new hair-powder in large quantities at Dresden, Leipzig, &c. Now it so happened, that some of this powder was used to dress Böttger's wig, and that the wearer observed a difference in it from the common sort, and complained of its greater weight. Questioning his servant on the subject, he learnt that it was earthy in its nature; upon which he tried it in his manufacture of porcelain; when he found to his exceeding joy that he had at length discovered the true secret of producing this beautiful substance, and that with this new earth he could make as white a porcelain as that of China.

This substance was long known in commerce as *Snorr's white earth*, from the name of the merchant who first discovered it: its exportation was forbidden under the most severe penalties, and it was carried to the manufactory by sworn agents, and in sealed casks. The precautions taken to insure secrecy were indeed almost incredible. The fundamental point of all the instructions given to the work-people was, "Secrecy to the grave." This motto was given out afresh to the superintendents every month, and was affixed to the doors of the workshops, so that all the inferior workmen might be constantly reminded of it. Whoever should betray any one of the secrets of the manufactory was threatened by the king to be shut up for life as a state prisoner in the fortress of Kœnigstein.

The manufactory of Albrechtsburg, at Meissen, was treated precisely as a stronghold, of which the drawbridge was only lowered by night, and entrance was strictly forbidden to all unconnected with the place: even the king, on bringing strangers of distinction to see the place, received a caution not to betray inadvertently any of its secrets.

Böttger was rewarded for his exertions by being placed at the head of the new manufactory in the character of director. So successful were his attempts at a complete imitation of the porcelain of China, that the most experienced eye can scarcely detect the difference in colour, form, painting, or gilding, between his works, still exhibited in Dresden, and those of the Chinese. Unhappily for himself, this clever and ingenious man, having attained the height of his ambition, began to take less interest in the subject which had formerly engrossed all his thoughts, and at length giving way to a luxurious mode of life, died at the early age of thirty-five years, in 1719.

The attempts to imitate Dresden porcelain now became numerous, and in some cases the resemblance was considerable, but it was only in external appearance, the essential qualities of good china being wanting. At length, however, certain individuals who did not feel that the stealing of a process is as culpable as any other kind of theft, seduced a few of the workpeople from their allegiance. Thus the porcelain factory of Vienna originated, in 1720, and thus in 1744, the Duke of Brunswick won over the potter Bengraf to his interest, who founded the manufactory of Furstenberg, on the Weser. At the same time and even earlier the secret had transpired in other quarters, and the manufacture was carried on in various parts of Germany, so as to become a source of profit to many sovereigns, at the same time that it afforded new objects of splendour and magnificence.

The porcelain-making mania had ere this spread to England. A soft ware of white clay, Alum Bay sand, and pounded glass was made at Chelsea and at Bow, but the manufactures do not appear to have been very successful until George II. imported workmen, models and materials, from Brunswick and Saxony. Chelsea porcelain of great beauty was produced between 1750 and 1755; the colours were fine and vivid, and a rich and peculiar claret was employed. So great was the eagerness to obtain it, that it was sold by auction to the highest bidders, the dealers rushing in crowds to compete for it. Bow china was somewhat similar, but the materials employed were not so fine. Another factory was established at Derby, where Chelsea artists, workmen and models, were introduced, and the union of the two factories was signified by the union of the respective monograms, that of Chelsea being an anchor, that of Derby the letter D. This factory did not remain long in existence, owing to disagreement among the partners; but its productions were of fine quality, and many of them from Flaxman's designs. The Worcester Porcelain Company was established in 1751, and was the first to make use of the Cornish stone or kaolin, discovered by Cookworthy in 1768. These works are still carried on with great success by Messrs. Kerr and Binns. In 1772 a factory was established at Caughley, Colebrook Dale, the productions of which are known as *Salopian ware*. Good porcelain was also made at Nantgarrow and Swansea, in Wales. Among the most celebrated factories of the present day are those of Stoke-upon-Trent, and the well-known names of Minton and Copeland at once suggest magnificent specimens of this manufacture.

The emulation of scientific men in France had been strongly excited by the progress of porcelain-making in Europe, and great efforts were made to produce porcelain equal to that of Saxony. M. Réaumur procured specimens of Oriental, Saxon, and French porcelain, and on breaking them he discovered that while the grain of the Chinese and Saxon pieces was compact, smooth, and shining, that of the French ware was not so close or fine, had no lustre, and resembled loaf sugar. By further experiments he found that true porcelain is a semi-vitrified compound, in which one portion remains infusible at the greatest heat, while the other portion vitrifies and envelopes the infusible part, producing the beautiful translucent and shining texturē. He next examined two sorts of porcelain earth received from China, one of which, called *pe-tun-tse*, was fusible, the other, called *kao-lin*, was infusible. The search for materials answering to these was diligently prosecuted and at last successful. The finest and most abundant supply of porcelain earth in France was discovered accidentally in

Digitized by Google

1768, by Madame Darnet, the wife of a poor surgeon, who observed in a ravine at St. Yrieix, near Limoges, an unctuous white earth, which she thought might be used instead of soap in washing linen. She showed some of it to her husband, and he, suspecting its real nature, took it to Bordeaux, and made it known to persons engaged in the search after materials for porcelain, who, on trial, found in it the very thing they needed as a base for the real hard translucent porcelain. This discovery, so important to France, does not seem to have been of any immediate benefit to the surgeon and his wife. M. Brongniart relates that in 1825 Madame Darnet was still living, and came to him in much misery to implore charitable aid, having travelled from St. Yrieix, on foot, to see him. He gave her immediately what she required, and subsequently obtained for her from Louis XVIII. a small pension. This he justly calls a debt, due from France for her discovery, which, though accidental, was the means of opening a vast source of wealth and industry to the nation. The manufacture of hard porcelain was soon established at Sèvres, which had already become celebrated for a very beautiful china, but such as is called *tendre* or soft.

During the Revolution many valuable specimens of Sèvres porcelain were destroyed along with the furniture of royal palaces and mansions. But the establishment of Sèvres was patronised and protected by the revolutionary government. In the year 1800 M. Brongniart was appointed director by the First Consul, and held the appointment for forty-seven years. He originated the celebrated *Musée Céramique*, a historical series of specimens illustrative of the art in all ages, and accompanied by collections of raw materials, tools, trial-pieces, models of furnaces, &c. of a highly instructive kind; not the least interesting collection being that of the *failures*, which show what it is fruitless to attempt in the ceramic art. This Museum, together with an original and interesting work from the pen of M. Brongniart, will always give his name a high place in the history of the porcelain manufacture. Brongniart was succeeded by M. Ebelman, who held the appointment for a year or two, and was then succeeded by the present director, M. Regnault, appointed by Napoleon III.

In Italy the porcelain manufacture was carried on near Florence at the beginning of the eighteenth century. Venice and Turin produced porcelain; but the most celebrated works were those of Capo di Monti at Naples, founded by Charles III. (1736), who worked with his own hands in the factory, and held an annual fair in front of the royal palace at Naples, where the royal productions were sold, and where, to become a purchaser, was said to be the sure road to favour. When Charles became King of Spain he founded a factory at Madrid, and the Neapolitan works declined. His successor Ferdinand allowed other porcelain works to be opened, and these further accelerated the decline of the royal factory. In 1821 the establishment was closed; but the specimens of *Capo di Monti ware*, which exist in the form of tea and coffee services, &c., are said to be some of the most beautiful specimens of porcelain ever produced, for transparency, elegance of form, and delicate modelling of the ornaments, which are in high-relief.

The factory at Madrid was carried on during several reigns, but was destroyed by the French in 1812. There is a manufacture of hard porcelain near Oporto.

The more curious and rare specimens of porcelain realise very high prices. A service of Chelsea ware has realised 1,200*l*, one of Sèvres of a good period 30,000 livres, and Dresden ware is equally costly. Even among modern manufactures, where great skill and taste are required, the prices are necessarily high. Mr. Minton received 1,000*l*. for a service of turquoise and Parian, and Lord Ward gave 1,500*l*. for a dessert service of Sèvres.

Encaustic Tiles.—The art of making bricks or tiles of enamelled pottery is exceedingly ancient, and was applied to the decoration, external as well as internal, of palaces and temples. A number of large edifices in Persia and Asia Minor are covered on the exterior with such tiles, and sometimes enriched in the interior with historical pictures made with vitrifiable colours. Among the ruins of Babylon a great number of fragments of ornamental bricks and tiles have at various times been found. M. Riche in his visits to those ancient ruins found in most of the excavations "fragments of beautiful pottery, and a great quantity of glazed tiles of surprisingly fresh and brilliant colours." Many of the mosques in Asia Minor are adorned with tiles of this description: that forming the tomb of the children of Ali, near Bagdad, has two domes completely covered with gilded tiles, while the walls are ornamented with various flowers. This edifice is said to have been built in 1581. There is a palace at Ispahan richly decorated with historical pictures composed of square tiles, in which five or six colours can be traced, and there are several other edifices in the same city, variously ornamented with coloured tiles. A small fragment from the great mosque at Jerusalem was of a beautiful turquoise blue, with ornaments of a deep blue approaching to black. Another, from Baalbeck in Syria, was of a hard and white, yet porous clay, with a thin pale bluish glaze, and black ornaments. The palace of the Alhambra in Spain is covered almost everywhere with encaustic tiles of great beauty, and one of these, when examined in the laboratory of Sèvres, was found to have a glazing in which lead was present, thus showing that the Arabs were cognizant of this kind of glazing, at least in the fourteenth century. This tile had the motto in Arabic, "*There is none strong but God*," and this motto is repeated thousands of times on the walls of the Alhambra.

In the museum of the East India Company are some fine examples of bricks and tiles with a brilliant glaze, brought from Gour, not far from Patna. The bricks are covered with rich ornaments in relief, white upon a black or deep blue ground, and in some cases the ornamental part is heightened with green or yellow. There are also red tiles and bricks from Nepal, richly ornamented.

Without further tracing the early history of encaustic tiles, we may simply remark that their use was immense and very widely spread, and that they formed the favourite covering not only for floors, but for walls, and even roofs. In some of our ancient churches specimens may still be seen, and it appears that during the middle ages the custom of inserting in the tiles the arms of founders and benefactors to the edifice became very common. Many of the larger abbeys had kilns of their own for the preparation of these tiles, and from this source also, it would appear, the parochial churches were supplied. An ancient tile-kiln was discovered some years ago, near Malvern, on land formerly belonging to the Priory there. The ancient pavement of the chapter-house at Westminster may be mentioned as one of the best preserved specimens of encaustic tiles.

In the present day, the taste for this kind of ornament has revived in a remarkable degree, and many of our churches now bear witness to the skill and judgment with which encaustic tiles are employed. The manufacture has, therefore, necessarily become active and important, and the processes are sufficiently interesting to be described in a general treatise on fictile ware.

VARIETIES OF CERAMIC WARE.

Every article in pottery, stone-ware, and porcelain, consists essentially of silica and alumina. These two substances are usually represented by flint and clay; but in the case of porcelain, where the white colour and translucency are required, a purer material than clay is found in *Kaolin* or porcelain earth. But not even the finest porcelain ever consists of the pure chemical compound silicate of alumina, while in pottery the impurities, such as iron, lime, potash, &c. give character to the ware. The reason why the pure silicate of alumina cannot be used, is to be found in the refractory nature of its component parts; so that certain fluxes are added to increase the fusibility of the two chief materials. In pottery these fluxes occur naturally in the impurities of the clay, and although more readily fired, the ware is opaque, whereas in porcelain, such a flux must be chosen as will not interfere with its whiteness and translucency. Pottery and porcelain wares are both distinguished by the terms *soft* and *hard,* which refer both to the composition of the ware, and the temperature at which it is fired. Common bricks and such earthenware vessels as pipkins, pans, &c. are soft, while fire-brick and crockery, such as stoneware, Queen's-ware, &c. are hard. Soft pottery, such as that composed of silica, alumina, and lime can be scratched with a knife or file, and would usually melt down at the heat required for the baking of porcelain. Stone-ware consists of silica, alumina, and baryta, and is in fact a coarse kind of porcelain. Hard porcelain has more alumina and less silica in its composition than the soft, and is fired at a stronger heat, the result being a denser kind of ware. Soft porcelain contains more silica than hard, and being combined with alkaline fluxes, its softness is shown in the ease with which it can be scratched, and its inability to resist a very high temperature.

MATERIALS OF EARTHENWARE.*

In the manufacture of earthenware, the choice of the proper description of clay, and the proportion of flint to be added thereto for the production of the kind of ware required, are matters of great importance. In this respect each manufacturer exercises his own judgment, keeping the proportions of these two materials secret; for on them are supposed to depend the peculiar excellences of his productions. The methods of combining the clay and flint are nearly the same everywhere.

Four kinds of clay are in common use in the Staffordshire potteries. These are called *black* clay, *cracking* clay, *brown* clay, and *blue* clay. The first two are brought from the south of Devonshire; the others from the Isle of Purbeck in Dorsetshire.

The black clay is so called from its colour, which is due to the presence of a portion of bitumen or coaly matter contained in it, which, however, entirely disappears when the clay is passed through the potter's oven, leaving the wares made of it nearly or quite white. Cracking clay is so called from its tendency to crack during its first burning; an inconvenience which is avoided by mixing it with other clays which have not this tendency: it derives its value from its extremely white colour. Brown clay comes white out of the oven, but is also liable to an imperfection called *crazing*, or cracking of the glaze. On this account some potters reject this clay entirely, but Mr. Parkes thinks the defect to arise from the ware being drawn out of the oven too soon, the glaze, which is a species of glass, requiring as perfect an annealing as glass itself. Blue clay is considered the best for common purposes, and fetches the highest price. It will bear a larger proportion of flint than any other, and on this account will produce a whiter ware.

---

* The writer has to offer his best acknowledgments to Messrs. Ridgwood of Hanley, to Messrs. Minton, and to Messrs. Copeland and Garrett, of Stoke-upon-Trent, in Staffordshire, for the liberal manner in which they allowed their extensive works to be inspected, and drawings made, for the purposes of the present treatise.

In addition to these varieties of clay, a fifth is largely employed in the manufacture of the finer kinds of earthenware. This is the *kaolin* or *china clay* of Cornwall, already referred to. It is obtained from one of the ingredients of granite, which is often found in nature in a partially decomposed state. Granite is composed of quartz, mica, and felspar; and the last named mineral is the source of china clay. The clay merchants in Cornwall prepare the clay for the potter in the following manner. The stone is first broken up by means of a pickaxe, and then thrown into a stream of running water. This washes off the light argillaceous or clayey parts, and keeps them suspended in the water, while the quartz and the mica thus separated sink at once to the bottom: at the end of these rivulets are *catch-pools*, where the water is dammed up, and time allowed for the pure clay to subside. This being done, the water is drawn off; the solid matter at the bottom is dug up in square blocks, and laid on what are called *linnees*, which are several connected series of strong shelves, arranged so as to allow of a proper circulation of air, in order to dry the clay. This being done, it is packed in casks and sent to the potteries under the name of china clay. Thus prepared, it is a white impalpable powder; and contains sixty parts of alumina and twenty of silica. A portion of undecomposed Cornish felspar is often added to the clay, as it serves by its fusibility to bind the ingredients more closely together. It is worthy of remark that although neither clay, flint, nor lime can be melted separately in the greatest heat of a porcelain furnace, yet when mixed together in proper proportions one mineral acts as a flux to the others, and the mass can be more readily fused.

Steatite or soapstone, a species of mica which is found abundantly in Cornwall, and also in the island of Anglesea, is also occasionally used in the manufacture of porcelain.

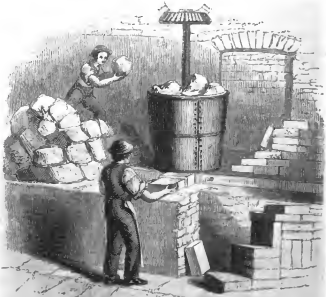
The flints employed in the manufacture of earthenware are obtained from the chalk districts, chiefly Gravesend and Newhaven. They are coated with a white crust, but are dark and clear within. Those which have brown or yellow spots on their fractured surfaces should be rejected, as these marks indicate the presence of iron, which would produce stains in the ware.

PREPARATION OF THE MATERIALS.

The preparation of the materials for the use of the potter is a work of considerable labour and care.

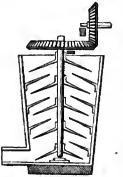
BLUNGING.

The clay is first mixed with pure water to the consistence of cream. This is called *blunging*, and is carried on in a trough about two and a half feet deep, as shown in the figure. The proper proportion of blue and white clay, being placed over-night in the trough with a quantity of water, is left to soak until the morning. It is then well incorporated with the water by means of a long blade of ashwood furnished with a cross handle at its upper extremity, and called a *blunger* or *plunger*. This is worked about violently in the trough in all directions until a smooth pulp is produced, a pint of which is, by the addition of water, made to weigh twenty-four ounces; but when china clay is used, a pint is made to weigh twenty-six ounces.



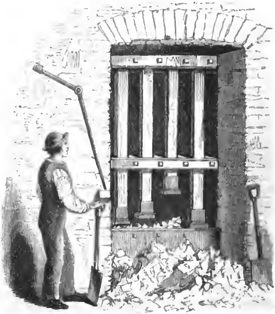
GRINDING THE CLAY.

In some establishments mechanical power assists the operation of blunging. The clay is thrown into a cast-iron cylinder four feet deep, and twenty inches in diameter. Through the centre of this cylinder runs an upright shaft, furnished with projecting knives arranged in a spiral line from top to bottom,



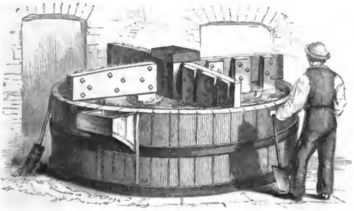
so that, as the shaft revolves, these knives not only cut the clay but force it downwards to the bottom of the cylinder. Parallel with, and corresponding to these knives, a second set is fixed in the interior surface of the cylinder, extending nearly as far as the shaft in the centre; and thus these two sets, one in motion and the other at rest, act like shears, cutting the clay into small pieces; in this divided state it is forced out through an opening at the bottom of the cylinder, whence it is removed to a vat and mixed with water, where the blunging is greatly facilitated by this previous cutting up of the clay. The mixing vat is provided with a perpendicular shaft furnished with cross arms, which by their revolution cause the finer particles of the clay to mix with the water, while any stony particles that may be present sink to the bottom. By these contrivances a pulp is formed as in the process of blunging by hand already described.

In order to reduce the flints to an impalpable powder, several processes are necessary. They are first burnt in a kiln for about thirty hours, and are allowed to cool before being taken out: in some places however it is the practice while they are at a red heat to throw them into cold water, the effect of which is greatly to increase their brittleness. They are next broken, for which purpose they are placed upon a strong iron grating, and struck by stampers or wooden beams shod with iron, weighing about a hundredweight each, and furnished at the upper part with projections or catch pins, which meeting with similar projections in a wheel on the opposite side, the stampers are raised in succession; and these, when left free by the rotation of the wheel, fall with great force and break the flints into fragments sufficiently small to fall through the grating.



FLINT MILL.

The fragments of flint thus prepared are next conveyed to the *flint pan*, which is a strong circular vat, ten or twelve feet in diameter. The bottom of this vat is formed of quartz or felspar in small blocks embedded in mortar, similar in composition to the material which is to be ground. In the centre of the vat is an upright shaft surrounded by a barrel or hoop fourteen inches high, to prevent the materials from being soiled by the moving power while being ground. Projecting from this shaft are four strong frames which serve the purpose of moving the runners, which consist of a very hard siliceous stone called *chert*, which is found in abundance in the neighbourhood of Bakewell in Derbyshire. Water to the depth of eight inches being put into the vat, the broken flints or felspar are added, and the central shaft being put in motion, the broken pieces are forcibly rubbed against the runners as well as against each other and the paving of the vat, so that in the course of some hours the flints are reduced to a fine powder, and the mixture has the consistence of thick cream.*



FLINT PAN.

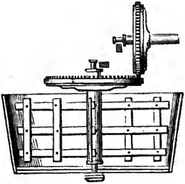
Before the invention of this mill by the celebrated Brindley, the flints were ground dry—an operation almost as fatal to the workmen superintending it as the dry grinding of needles and edge tools is, or till lately, was. The air of the room being charged with the finer particles of the flint, entered the lungs and did much mischief. The introduction of the wet method, however, has entirely remedied this serious objection, as the ventilating apparatus has in the case of dry grinding.

The selection of the stones employed in the construction of the flint mill is a point of importance, as the goodness of the pottery depends in great measure on this circumstance. Mr. Parkes records an instance of severe loss having been sustained by some of the first houses in the trade, in consequence of their having been supplied with quantities of prepared flint which had been ground with stones containing a large proportion of carbonate of lime: this being mixed with the flint, and eventually with the ware itself, rendered it fusible at a lower heat than usual, so that several ovens full of ware were fused down before the error was discovered.

---

* Smaller pans of the same construction from four to six feet in diameter are used for grinding the felspar, broken porcelain, bone, and other materials used in the composition of earthenware, as also the different glazes used for covering the ware after it is baked.

When the flints are sufficiently ground in the flint-pan, the creamy mixture is transferred to another vat containing a considerable quantity of water. This vat is also furnished with an upright shaft and arms, by the revolution of which the finer particles of flint are kept suspended while the larger and heavier particles sink to the bottom. The water containing the finer particles is then drawn off into a reservoir, and when the fine powder has subsided the water is allowed to flow off. The flint powder is considered as fit for mixing with the clay when a wine pint of it weighs thirty-two ounces, while an equal bulk of the diluted clay should weigh twenty-four ounces. By thus taking the densities of the two principal ingredients, the manufacturer is enabled to mix them in the proportions which he judges best adapted to the kind of

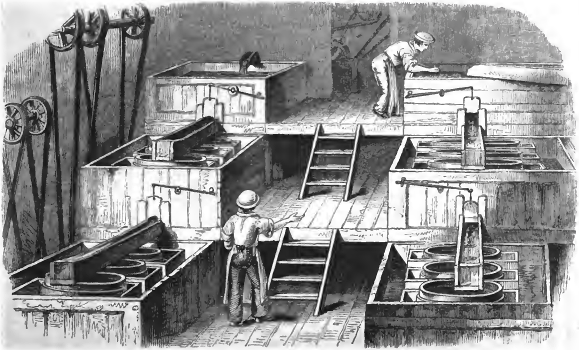


ware intended to be made; but in this respect the practice of manufacturers, as already stated, varies considerably.

MIXING THE MATERIALS.

The clay and the flint being thus reduced to a state of minute division, are mixed in the proper proportions, and intimately united by agitation. The mixture is then passed through sieves of hard spun silk, manufactured expressly for the purpose. These sieves go on increasing in fineness, so as to prevent any unbroken pieces from remaining in the mixture, and to reduce the whole to a state of the utmost uniformity and smoothness. These sieves are arranged on different levels, as shown in the engraving on the next page, and are so connected with the machinery as to receive a sort of jigging motion, whereby the mixture passes freely through.

The fluid mixture of clay and flint is technically called *slip*, and as the water which has been so profusely employed in its preparation is, as it were, a sort of tool useful in the production of a result, but which may be laid aside when the result is accomplished, so now it becomes necessary to get rid of most of the water, and to bring the mixture of clay and flint to a doughy consistence for the use of the potter. As heat is the most convenient agent for getting rid of water, the slip is conveyed to the *slip-house* and boiled in the *slip-kiln*. The slip-house is a long low building, standing by itself, the tiles of the roof being placed half-way apart to allow of the more ready escape of steam and vapour. The slip-kiln consists of long brick troughs, with flues under them, of sufficient size to heat the mixture to the boiling point. It is necessary to keep the mixture constantly agitated during the early part of the evaporation, to prevent the heavier flint from subsiding; for if this were



MIXING THE INGREDIENTS.

not done, one part of the clay would contain too little, and another part too much flint. There is, also, a tendency on the part of flint and clay, when water is present, to form a sort of mortar which speedily hardens, but this is prevented by diligent stirring. When bubbles of steam cease to be formed on the surface of the slip, and portions cut out from different parts of the mass appear to be of the same texture and sufficiently hard, the fire is lowered, and the mass is quickly removed from the kiln to undergo the process of *wedging*. The slip is generally in the kiln twenty-four hours.

SLIP-KILNS.

The mixture of clay and flint after it has left the kiln ought to be kept for a considerable time, in order that the materials may become more intimately united than they ever can be by mere mechanical force. During this *ageing*, as it is called, a fermentation takes place; carbonic acid and sulphuretted hydrogen are liberated, and the mass improves in texture and colour. There are probably certain carbonaceous and organic impurities in the clay, or in the water, or both, which produce the fermentation. In China it is not uncommon for the prepared clay to remain fourteen or twenty years before it is thought to be in a fit state for use; and Mr. Parkes states, that in some districts, it is customary for a father to prepare as much porcelain clay as will be sufficient for the use of his son throughout the whole period of his life. In England, however, this point is not sufficiently attended to, although every manufacturer is aware of its importance; want of room, of time, and often of capital, occasion it to be sometimes used warm from the slip-kiln, and not uncommonly when it has been lying for only a few hours or days.

The heat to which the mixture of clay and flint is exposed in the slip-kiln drives off the greater portion of the water in the form of steam, as already stated. As the evaporation proceeds, and the mass increases in density, the expansion of the water into steam fills the clay with little vessicles, which must be got rid of, together with air bubbles entangled with the clay; for, if allowed to remain, they would form blisters or warts in the ware. This is accomplished in a remarkable manner: the mass from the kiln, extending many yards in length, is cut up into wedges by means of a sort of spade, and these wedges are turned over and dashed against each other. In this way the pile is worked two or three times in the course of a few months, during which the whole mass becomes more uniform, of finer grain, and not so liable to crack or become disfigured in the baking, as the ware made with more recently formed paste.

This process, which is called *wedging,* is not however sufficient to get rid of air bubbles, nor to impart to the paste sufficient uniformity and smoothness. It has to undergo a more refined and elaborate process called *slapping.*

The workman called the *slapper* takes a mass of the paste, weighing from sixty to seventy pounds, and dashes it down upon a bench before him. He then

Digitized by Google

cuts off a portion by drawing through it a wire, furnished with a handle at each extremity, and taking up the piece thus separated, he turns it over, and dashes it down with all his strength upon the remainder of the mass. The wire is passed through a second time in another part of the lump, and the divided portion is again taken up and dashed forcibly down. This operation is repeated forty or fifty times, during which every portion of the clay is in turn brought to the surface, care being taken to preserve the *grain* of the paste; that is, the layers are slapped parallel to each other, and not at right angles or obliquely, for if this were done, the various segments would not re-unite in the slapping, and the ware would be liable to fall apart in the baking.

In preparing the paste for the potter, it is usual to mix with it portions of paste produced by the process of *turning*, hereafter to be noticed; as, also, any vessels which have been accidentally spoiled previous to baking. This material is generally of a different colour to the paste now under notice, and it is curious to notice how perfectly the operation of slapping blends the whole into one uniform mass; two masses of clay of different colours being thereby formed into one mass of a colour intermediate between the two. Air bubbles are also effectually got rid of by this process, and the paste is thus prepared for being fashioned into some of the endless variety of useful and ornamental articles in earthenware.

In the preparation of paste for the manufacture of porcelain, the China clay of Cornwall is used in combination with ground flint and felspar; to this is added a proportion of calcined bones, (which are supposed to improve the transparency of the ware,) and a small quantity of gypsum or sulphate of lime. Fragments of broken porcelain ground to a fine powder sometimes enter into the composition; and should this material not be at hand, small slips of it are prepared from clay, flint and gypsum, the two latter ingredients being in excess; these slips are baked into porcelain, and then broken up and ground to powder for mixing with the other materials. Different writers mention other ingredients, such as a frit composed of nitre, soda, alum and selenite, together with ferruginous sand and a small quantity of common salt.

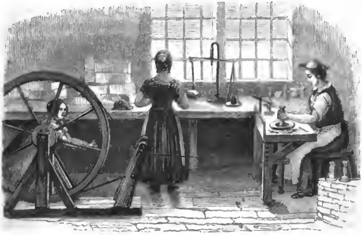
THROWING.

Articles in earthenware are brought first into shape by one of three different processes, named *throwing*, *pressing*, and *casting*. Of these, throwing is the most ancient as well as remarkable, for by it vessels of elegant and beautiful forms are produced by the hands of the potter, with such precision and rapidity as may well excite the admiration of the spectator. In pressing and casting, the clay receives its form from plaster-of-paris moulds, and the articles are produced without any remarkable degree of skill on the part of the workman.

The thrower performs his work with the assistance of the ancient *potter's wheel* or *lathe*, consisting of an upright shaft, about the height of a common table, on the top of which is fixed a disk of wood of sufficient diameter to support the largest vessel that is made by this means. The lower end of the shaft is pointed, and runs in a conical step, and the upper part in a socket a little below the circular board. The shaft has a pulley fixed upon it, with grooves for three degrees of speed, over which an endless band passes from a fly-wheel, by the revolution of which any degree of speed may be given to the shaft and its top-board. When this wheel is small, it may be placed alongside, as in the turner's lathe, and it is then driven by a treadle and crank: but when of large dimensions, by the arms of an assistant.

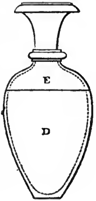
Digitized by Google

The mass of dough to be thrown is adjusted to the size of the vessel required, for which purpose the mass, as it is received from the slapper, is cut up into portions with a brass wire: each portion is weighed separately, well slapped between the hands to expel water and air bubbles, and then rolled up into a ball. This is usually done by a second female assistant, called the *baller*. The thrower, seated with one foot on each side of the wheel-head, with his elbow supported on his knees when his hands require to be kept steady, takes one of these balls, dashes it down upon the centre of the revolving board, and with both hands previously wetted, and occasionally dipped into water near him, he squeezes up the clay into a high conical column, and again forces it down into a lump, so as to get rid of any remaining air bubbles. With one hand or finger and thumb in the mass, and the other on the outside, or with his fingers only, he gives the first rude form to the vessel, and with a piece of horn, slate, or

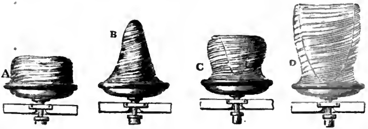


THROWING.

porcelain, called a *rib*, which has the profile of the shape of the vessel, he smoothes the inner surface, gives it the proper shape, and removes the inequalities left by the fingers. In the mean time, the assistant keeps the wheel in constant motion, varying, however, the degree of velocity, according to the directions of the thrower, who requires different degrees of speed at the different stages of his work. In order to make a number of vessels of exactly the same size, he does not rely entirely upon his eye; he is furnished with a very simple kind of gauge, consisting of a peg, or stick, placed opposite to him, at a certain distance from the centre of the vessel, whereby he is able to judge of the required height and diameter of the vessel which is being formed. It is scarcely necessary to remark, that the thrower produces only such vessels as are circular, such as tea-cups, basins, &c. Handles, spouts, and ornaments, when required, are added afterwards. As fast as the thrower has completed one vessel to his satisfaction, he cuts it off at the base by means of a fine brass wire; the baller then hands him another ball, and dexterously lifts off the vessel, (which is said to be in its *green state,*) places it on a board, and when a sufficient number are collected, they are removed in fine weather to the open air, and in moist weather to a warm room, where they gradually part with moisture, and are fit for the next process, which is *turning*.



The following figures will further assist the above description of throwing. In order to form the lower part of the vase D, the thrower dashes upon his wheel the lump of clay, A; this is worked into the conical mass B; then into the rude cup, C, and lastly into D. It is the business of the turner to reduce the thickness of the mass, and to improve



the shape. E, on the wheel, is intended for a portion of the cover of the vase. It will be observed that in all the figures on the wheel, a *spiral grain* is given to the clay, which is found best to retain the form given to the plastic material.

TURNING.

The operation of turning, precisely resembles that by which wood, ivory, metal, and other substances are formed into articles with circular surfaces; and it is a curious sight to watch a rude clay cup or bowl spinning quickly round in the turner's lathe, with long and broad shavings flying off from it, under the operation of a chisel and other cutting tools. The thrower not being able to form vessels sufficiently thin, or to produce that finish and polish which are expected in articles of this kind, renders the process of turning one of considerable importance. "It requires considerable dexterity in the workman, to avoid destroying or fracturing the vessels, while forming them to their requisite size, thickness, and correct shape of circular vessels; and it presents numerous opportunities for the exercise of skill, taste, and genius, in giving to the several parts the rings and rims required, and to the whole all the elegance suggested by the pattern, and the little niceties, either with much difficulty, or by no effort, obtainable when on the throwing engine."*

In order that the turner may stand quite steady to his work, motion is given to his lathe by an assistant, called the *treader*. This is often done by a female, and as her right foot only is employed during the turning, she is able to attend to the green vessels on the board, moistening their upper edges, and clearing away whatever may interfere with the turning. "The position of the turner while employed on earthenware is the reverse of that of the wood turner; for instead of standing exactly linear with his lathe, or aslant a little from the head-stock, he looks towards this, and remains at entire freedom from every thing that might render him unsteady. On the chuck is a clay ring, kept scarcely moist. The vessel to be turned is put on the chuck, and as soon as the treader gives motion to the spindle, the turner presses with his tool or finger the upper edge, already moistened into the clay ring. Next, placing his tool opposite the transverse axis of the piece, he carefully cuts away all surplus clay left by the thrower, and reduces it to the precise thickness required. In very valuable articles the turner weighs each vessel. The ornamental portions are formed, and when engaged in *engine turning*, while the spindle is in slow motion, the back spring causes the incisions of the circular plate or movement to bring the vessel nearer to the tool, and those parts are in consequence cut away in diamonds, dice, or other fanciful indenting; and the full part carries it away again, so as to form these dices, &c. at distinct distances all round the vessel. When all the cutting away of the clay has been completed, the treader very expertly gives to the spindle a retrograde motion, during which the turner applies the flat surface of a broad tool on the upper part of the vessel, and by gentle pressure thereon, gives to the whole vessel a solidity not previously existing, and a glossy smoothness of surface, removing all inequalities of surface left by the prior manipulations. The vessel is next cut loose from the clay ring, and placed on a board, for the handler, or to dry for the biscuit oven."

---

* Encyclopædia Metropolitana.

Handles, spouts, and other additions are attached to the articles by means of slip, which unites them perfectly in a very short time. The superfluous clay about the handle is scraped off with a knife, and the vessel cleaned with a damp sponge, which gives it a uniform appearance. The clay for the handles, &c., is first formed into pipes at a small press, which forces the clay through a metal tube of the required size and form. This clay pipe is then cut up into lengths, and bent into the required shape, for a handle, &c. Spouts are formed by inserting a pin of the proper size into the metal tube, and forcing the clay between the two. Ornamental handles, spouts, &c. are formed by pressing clay into plaster-of-paris or steel moulds; figures of animals, foliage, &c., are similarly formed, and are afterwards attached to the vessel by means of slip. In some cases copper moulds are used, smeared with oil, to cause the ornament to deliver itself freely. Flowers and foliage, &c. are also formed by hand, with considerable dexterity and attention to botanical character; as the writer had an opportunity of witnessing at the celebrated porcelain works at Meissen, near Dresden.

Digitized by Google

PRESSING.

The second method of forming articles in earthenware is by *pressing*, which is the same in principle, only on a larger scale, as the method just alluded to, of forming ornaments in plaster moulds. Plates and dishes are made by this method.

The plaster moulds used in pressing are numerous; a complete set being required for every new pattern, and for every size of the same pattern. Plaster-of-paris, gypsum, or sulphate of lime (the same substance under three different names), possesses the useful property, when recently burnt, of combining with water, so as to form a smooth, hard kind of mortar. When received at the manufactory in its crude state, it is ground between a pair of stones in a mill, similar to that used for grinding corn. This powder is next heated in a kiln, where it parts with a large quantity of moisture; this is called *boiling;* and when the process is complete, the powder is called *boiled plaster.*

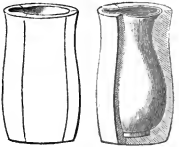
A model of the article required to be executed being prepared, it is placed on a board of the proper size, and at the distance of the intended thickness of the mould, a *cottle*, or bat of clay is fixed. A portion of the model is also covered with clay, and the exposed portion is brushed over with a wash, formed by boiling a solution of potash, soft-soap, and china clay; this is to prevent the plaster from sticking to the model, and also to impart to the mould the requisite smoothness.

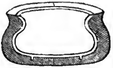
A quantity of boiled plaster being quickly mixed with water, is poured, while still fluid, around and over the model, till the proper thickness is attained. Considerable heat is given out during the combination of the water and the plaster, but in a very few minutes the plaster is sufficiently *set* to bear removal.

The clay cottle is then taken away, the other parts of the model are covered with plaster, and the mould is thus completed. In a few hours it is taken apart, and the model removed, when the mould presents an accurate impression of the model in all its minute details. When the mould is properly dried, it is fit for use.

Moulds for plates and dishes, and similar shallow articles, consist of only one piece, and are formed by taking the impression of the upper surface of the model of the plate, &c. in plaster; the plate-maker placing the mould upon a *whirler*, formed of a thick block of plaster turning freely round in a horizontal plane, takes a weighed ball of clay, and flattens it out with a block of plaster with a broad base, called a *batter*. When a large mass of paste is required, as for a large dish, a moistened sheepskin is spread on a marble table, and over this the paste is extended with a rolling-pin, supported on two guide rules. The extended paste is then lifted up upon the skin, which prevents it from falling to pieces, and being placed upon the mould, the skin is removed. The workman then proceeds to work the paste down upon the mould, pressing out the air with a small slab of baked porcelain, then smoothing and adjusting it with a piece of flexible horn, thirdly, rubbing it well with a wet sponge, and, lastly, with wet leather. The edges then being trimmed, and the maker's name, or other inscription or mark stamped upon the back, a boy takes up the mould with the plate upon it, and conveys it to a warm room, heated by means of an iron flue. A series of wooden shelves are ranged round this room, upon which the moulds are placed. In about two hours the plate is sufficiently dry to be removed from the mould, and this, which has absorbed moisture from the paste in contact with it, is unfit to be used again immediately; but, by keeping a number of moulds going, those first used become sufficiently dry to be employed again, so that each mould can thus be used five or six times in a day. A man, with the assistance of a boy, will make 400 or 500 plates in a day.

Such is the simplest form of pressing. Deep vessels, such as ewers, vases, &c., are formed by what is called *hollow ware pressing*, or *squeezing*, for which purpose the mould is generally made in four parts, accurately fitting together. The presser prepares for his work by getting ready a number of crusts of clay, called *bats*, of the proper size and thickness for pressing into the separate parts of the mould. From a properly-slapped mass of clay and flint before him, he cuts off with a brass wire, a piece of the proper size, which he kneads between his hands into a ball, and then dashes it down upon the bench before him; he then beats it out, with a plaster batter, to the required thickness and shape, and puts it aside for future use. When a sufficient number of bats is collected, the mould, or a section thereof, is put upon a whirler, and one of the bats is *bossed*, or forced into it with a moist sponge. The clay is also forced into all the parts and corners of the mould by working it about with the thumbs. When all the sections of the mould are thus filled, and the surface





smoothed with a moist sponge, the edges are trimmed with a sharp knife, and moistened with slip; the parts of the mould are next carefully brought together, and secured by a strap passed round them. The presser then passes his finger up every joint, so as to form a channel into which a thin roll of clay is inserted, which is worked in first by the finger and thumb, and then smoothed with moist leather, or a cow's lip, on account of its convenient form. All marks are carefully removed with a moist sponge and the inside is then washed with pure water. The mould having been set aside for a short time to dry, is again placed on the whirler, and polished with a flexible plate of horn. The mould is then placed in a warm room, and, when sufficiently dry, the article is taken out to be *fettled*, or trimmed with proper tools, so as to get rid of any appearance of seams; superfluous portions of clay are removed, and the exterior surface is then cleaned and polished with a moist sponge; the handles, and other appendages, are added; it is, lastly, polished with the horn, and is then set aside to dry previous to baking.

HOLLOW WARE PRESSING.

In some establishments where original articles of great taste and beauty are produced, models in clay must first be formed by an experienced modeller, who is generally an artist of considerable skill. When the design is elaborate, the mould is of course complicated. The writer saw at Meissen models for four vases, emblematical of the ancient elements—fire, air, earth, and water, the moulds for which consisted of 150 separate pieces. The impressions as delivered from the moulds are put together by means of slip, and any little ornaments, such as flowers, foliage, &c. which are made by hand, are attached by the same material.

Where the ornaments are of a simple character, the articles are formed by the union of throwing and moulding; as for example, coffee cups with a raised ornament in the inner rim, which were being made at the time of the writer's visit to Minton's porcelain works. Each cup was first formed by throwing; it was then put over a mould to receive the interior ornamental border; the throwing was next repeated, or as it is now called *laying*, the object of which was to bring the paste close up to the surface of the mould; by this method the inside of the cup is finished; the outside being afterwards brought into proper shape, and the cup made thin and light by turning. When embossed ornaments are on the outside of the vessel, the reverse of the above process is adopted, the paste being put into the mould while the inside of the vessel is formed by throwing. Scolloped edges are sometimes produced by the turner, but more usually they are formed by hand with a knife.

CASTING.

In forming delicate fragile articles intended for ornament rather than use, the process of *casting* is often adopted. For this purpose the clay and flint are mixed with pure water to a creamy consistence, and in that state poured into the moulds. The plaster quickly absorbs water from that portion which comes in contact with it, and hardens it sufficiently to allow of the central and still fluid portion being poured off. A coating of slip is thus left attached to the mould, and being left to dry for a short time a second portion is poured in; this, however, is thicker than the first charge, and serves to strengthen and support the thin layer already adhering to the mould: the fluid portion being poured off, the mould with its contents is placed in a stove until sufficiently dry to be separated. The cast is then taken out, and while yet in its green state it is carefully examined by the modeller, and any little defects corrected. By this method are formed the porcelain statuettes now so common. The lace which adorns many of the female figures, is put on together with other minute ornaments after the figures are taken out of the mould. The lace is formed of cotton thread, manufactured for the purpose; and this being dipped into slip, imbibes a sufficient quantity of the porcelain material to take the place of the thread; so that when the latter is destroyed by the heat of the furnace in baking, the lace appears as if it had been originally formed of real porcelain.

BAKING THE BISCUIT WARE.

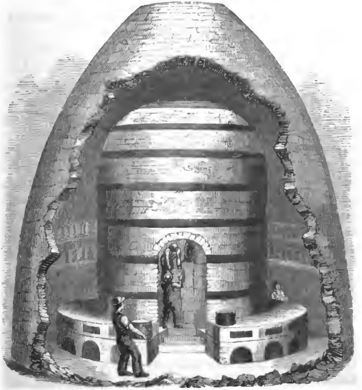
The articles produced by any of the processes already described, are kept in a heated room until they have parted with much of their moisture. In the course of drying, they gradually assume the colour of the dried plaster of a new wall, and when the overseer pronounces them to be fit for the kiln, they are packed in coarse strong vessels called *seggars*, for the purpose of protecting them from the direct action of the fire and the products of combustion, which would soil and otherwise injure them. Most of the seggars are oval in shape, and greatly resemble a lady's band-box without the cover; the usual dimensions are two and a half by two feet, and twelve inches deep:—those used for plates are cylindrical, and vary in depth from eight to fourteen inches; the usual dimensions of the oval vessels are twenty-two and fifteen inches. The seggars are made of the marl of the Staffordshire collieries: it consists of gray silicious shale and carbonaceous schist. It is prepared for use by exposure to the weather, and when reduced to powder is mixed with old ground seggars. The clay thus produced is well kneaded, rolled out into shape, and the seggar is formed by folding the clay over a hollow wooden mould. The seggars require careful drying and firing before they are fit for use.

In filling the seggars, the pieces are prevented from sticking together, by interposing between them a quantity of sand or powdered flint. Many articles in soft porcelain are firmly imbedded in dry flint powder, which gives them support, and prevents them from warping in baking. Saucers are kept in form by an earthenware ring, called a *saucer setter ring;* cups have an earthenware ring on the top of each, and are not allowed to touch each other in the seggar. As the seggars are filled, they are conveyed to the furnace, and are piled up one over another, the flat bottom of one seggar serving as a cover to the one immediately below it. They are separated, however, and made tight, by a roll of clay on the rim of each seggar; each pile of seggars as it stands is called a *bung.* Considerable skill is required in arranging the seggars in the oven, in order that the various articles may receive the required amount of heat. The largest and coarsest pieces are usually placed on the floor of the oven. About thirty thousand pieces of ware are usually included in one baking.

An accurate idea of the appearance of the oven or kiln may be formed from the engraving on the next page, which represents the kiln before the fire is applied, and while the seggars are being arranged in it.

Digitized by Google

A portion of the outer cone of brick-work, or *hovel*, is removed in order to show the interior arrangements. The kiln itself is a massive cylinder of brick-work, bound with iron bands, and surmounted by a dome, with an aperture in the top, to allow of the exit of smoke; this hole is situated immediately under the chimney of the hovel. The kiln is surrounded by a number of fires and flues skilfully arranged for producing a high and equable temperature within. The use of the hovel is to protect the kiln from the cooling effect of air and rain, and to furnish a chimney for the escape of the smoke. On shelves within it are arranged



BISCUIT KILN.

Digitized by Google

seggars in a *green* state, where they are dried previously to baking. When the kiln has been properly filled, the doorway is carefully bricked up, the fires are lighted, and from that time till the baking is completed (a period of from thirty-three to forty hours for porcelain, and from forty to forty-eight hours for flint-ware), the kiln is anxiously watched by experienced workmen. The heat employed should be just sufficient to drive off the moisture and agglutinate the particles which compose the ware. It should never be sufficient to fuse them; for if this were done, there would be danger of their breaking down and becoming spoiled.

The fires are usually lighted at six o'clock in the evening from a supply of burning coals outside the hovel, prepared some time before. In the course of three or four hours the fires have gained considerable force, and the flame ascends completely through the cylinder into the chimney of the hovel. Coals are added from time to time, and the draft is properly regulated. In the course of the night the flames may be seen issuing from the chimney. Early in the morning the fireman takes out his ***first watch*** to see how the baking goes on.

These watches or *trial pieces* are rings made of Staffordshire fire-clay, which has the property of assuming different shades of colour at different temperatures. A number of these are placed in a seggar opposite a hole in the cylinder, and the fireman, removing the clay stoppel from this hole, inserts a long iron rod, passes the end of it through one of the rings, and withdraws it. When it is cool he is able to judge of the heat of the kiln, and the consequent state of the ware in the seggars by the appearance of the ring, and he increases or lowers the temperature accordingly. When by frequent inspection of the trial pieces the baking has been judged sufficient, the firing is discontinued, the furnace and ash-pit doors are closed, the fire is allowed to go out, and the contents of the oven are then left to cool gradually during twenty-four or thirty hours. In the course of one baking the kiln consumes about fourteen tons of coal, of which four are put in the first day, seven the next day and following night, and the last four to give the strong finishing heat. In this operation it must be admitted that the coal is wastefully expended; accordingly, other arrangements of the furnace have been proposed, and gas has been suggested as an economical source of heat.

When the ware is removed from the kiln it is in the state called *biscuit,* not because it has been *twice cooked* or baked, as the name implies, but from its resemblance, both to the eye and to the touch, to the dry and rough surface of well-baked ship-bread.

Some articles, such as wine coolers, butter coolers, and water bottles used in the East, called *alcarrazzas,* are finished when brought to the state of biscuit. Water contained in these vessels slowly oozes through the substance of the ware, and forms a dew on the outside, the evaporation of which carries off so much heat as to reduce the temperature of the remaining liquid many degrees below that of the atmosphere. This effect is proportionally increased by suspending the porous vessel in a current of air.

When the ware is removed from the oven, it is carefully taken out of the seggars, placed in baskets, and conveyed to the biscuit-room, where each article is examined, and struck with a piece of wood, its sound indicating whether the baking has been properly conducted. Considerable shrinkage has taken place in the ware, in consequence of the high temperature to which it has been exposed; for it is a curious property of clay to contract, not to expand by heat, as most other bodies do; not that there is, in fact, any peculiarity in this respect as regards clay, but it retains its moisture so obstinately, that a very great heat is required to get rid of it, and the shrinkage is occasioned by the passing off of moisture, and the consequent contraction of the clay. When this is got rid of, the clay expands, like all other solid bodies, by heat; but while at a high temperature a more intimate union takes place between the clay and the flint and other ingredients of the ware, so that when cooled again and moistened, the ware does not return to the dimensions which it had in the green state. Hence, in making articles to pattern, it is necessary in the first instance to make them larger than the model, in order to allow for shrinkage.

GLAZING BISCUIT WARE.

Such articles as are pronounced perfect in their biscuit state are ready for *glazing;* but if the ware is to be covered with any design or ornament, this is first added by printing, or painting by hand, in enamel colours, as will be described presently. White and cream-coloured wares require only a coating of glaze to fit them for the market.

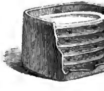
There are various kinds of glazes, all of which possess the property of melting into a glass, so as to cover and completely protect the porous fragile biscuit-ware, rendering it impermeable to water and other fluids, improving its appearance, and preventing it from crumbling and decomposing by use, and by exposure to the air.

The composition of glaze is another of the secrets of this art, each manufacturer having his own recipes; they generally contain flint and an alkali, the usual ingredients of glass, with sufficient lead to render them fluid. They are applied either in the *raw* or the *fritted* state. In the one case the ingredients are reduced to powder, mixed up with water to a creamy consistence, and then brushed over the biscuit. In the other case the ingredients are melted or fritted in a furnace, which ensures their chemical combination; a semi-transparent glass or enamel is thus produced, which is reduced to powder, and applied in the same manner as raw glaze.

There are three principal glazes; one for the common pipe-clay, or cream-coloured ware; a second for the finer pipe-clay ware, to receive impressions,—this is called the *printing body;* a third for the ware which is to be ornamented by painting with the pencil. According to Dr. Ure, the glaze of the first or common ware is composed of fifty-three parts of white lead, sixteen of Cornish stone, twelve of flints, and four of flint or crystal glass; or of forty of white lead, thirty-six of Cornish stone, twelve of flints, and four of flint glass. These ingredients are applied raw. The glazes intended to cover all kinds of figures printed in metallic colours, consist of twenty-six parts of white felspar, fritted with six parts of soda, two of nitre, and one of borax; to twenty pounds of this frit, twenty-six parts of felspar, twenty of white lead, six of ground flints, four of chalk, one of oxide of tin, and a small quantity of oxide of cobalt, to take off the brown cast, and give a faint azure tint, are added. The stone ware which is to be painted is covered with a glaze composed of thirteen parts of the printing colour frit, to which are added fifty parts of red lead, forty of white lead, and twelve of flint, the whole having been ground together. It is stated that these compositions produce a very hard glaze, which preserves for an indefinite time the glassy lustre, is not subject to crack and exfoliate, cannot be scratched by the knife, is not acted on by vegetable acids, and does no injury to articles of food kept in contact with it. There is, however, an objection to the use of lead in glazes, not only on account of the injury to the health of the workmen, especially when raw glazes are employed, but from the liability of the lead to become soluble in acids, and to mingle with the food. Hence the use of lead in glazes is becoming much less common. At Messrs. Ridgwood's the writer saw a large quantity of glaze flowing from the fritting-furnace, in the composition of which no lead had been employed.

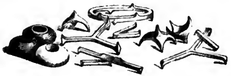
The fritted glaze having been ground to a fine powder, is put into the *mixing-tub*, where the other ingredients are added. The whole being well worked together with water, the mixture is drawn off into a *dipping-tub*, in which a quantity of common salt is sometimes added to make the water more buoyant, and thus to prevent the metallic oxides of the glaze from subsiding.

The articles in the biscuit state being carefully brushed from dust or powdered flint, are immersed one by one in the glaze-tub; as each article is taken out, the *dipper* skilfully shifts it into different positions, so as to distribute the glaze powder uniformly over the surface, and to prevent it from being thicker in one part than in another. While this is being done, the watery particles of the glaze are absorbed by the porous biscuit, leaving the surfaces covered with a thin coating of white powder; the article is then set aside to drain, either upon a hair sieve, or upon a board containing rows of projecting points. When sufficiently dry, the glaze has very much the appearance of a uniform coat of whitewash, entirely concealing the biscuit, together with any figures which may have been previously printed or painted upon it. The articles are again carefully packed in seggars, and various arrangements are made to prevent them from sticking together. It is obvious that a layer of sand or flint cannot be used for the purpose, as in the biscuit oven, since the glaze in melting into a glass would unite with the sand or flint. On the inside of the cylindrical seggars, strips of seggar clay are fixed, prepared with triangular holes in which *stilts* of clay are inserted, in order to support the pieces of ware and keep them separate during the baking. Other articles of pottery are separated by various forms of rests and supports called



SEGGAR.

cockspurs, *stilts*, *triangles*, &c. The seggars are then conveyed to the *glaze-kiln*, which is similar in its arrangements to the biscuit-kiln, but of smaller dimensions. The heat employed is just sufficient to fuse the glaze into a transparent glass, and to enable it to unite perfectly with the surfaces of the biscuit. Rings of clay covered with glaze (as shown in the figure,) are drawn out from time to time, whereby the workman ascertains the state of the furnace.



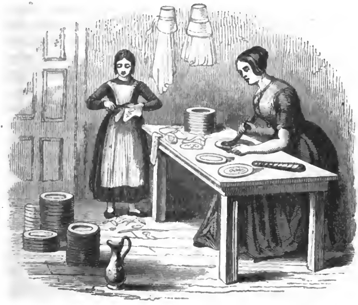
WATCHES, COCKSPURS, TRIANGLES, AND STILTS.

In the manufacture of coarse stone-ware, it is desirable for the sake of economy to complete the firing of the biscuit and of the glaze at one operation. Accordingly, when the ware has attained a high temperature in the kiln, a quantity of moist salt is thrown in. This is immediately volatilized and decomposed. Now, salt is a compound of chlorine and sodium; the liberated chlorine unites with the hydrogen of the decomposed moisture, and forms hydrochloric acid, which escapes, while the oxygen of the water goes to the sodium to form soda. This soda combines with the silica of the ware, forming silicate of soda, which, with the silicate of alumina of the ware, forms a fusible double alkaline silicate or glaze on the surface.

PRINTING ON BISCUIT-WARE.

When the ware is to be ornamented with a pattern, this is generally added before the glazing. The blue of the common dinner-service is produced by means of oxide of cobalt, mixed with ground flint and sulphate of baryta, in certain proportions, according to the shade required. These materials are fritted and ground, and before being used they are mixed with a flux, consisting of ground flint and thick glass powder, which serves to fix the colour upon the biscuit, and to prevent the glaze from displacing the lines of the pattern. The colour thus prepared is then mixed with linseed-oil (previously boiled to the consistence of honey), resin, tar, and oil of amber, forming altogether a very viscid kind of printer's ink, which is liquified for use by spreading it out upon a hot iron plate.

The pattern is engraved upon copper plates, in the usual way for copper-plate printing. The printer covers the engraved surface of the plate (previously made hot at a stove,) with the colour prepared as above; this he does with a leathern *dossil*, and then scrapes off the superfluous portion with a pallet-knife, and lastly cleans the plate with a dossil filled with bran. The lines representing the pattern, which are cut rather deeply, are thus charged with ink, while the smooth, unengraved portions of the plate are clean. The pressman then takes a sheet of thin yellow unsized paper, intended to receive the impression, dips it into soapy water, and lays it moist upon the copper-plate. The plate is next passed through a cylinder press, and the paper receives the impression of the pattern. The soap enables the paper to come off more readily from the copper; and when they are separated, the paper is handed to a little girl, named the *cutter*, who cuts the pattern into its separate parts, clears away white unprinted paper from about them, and places them by the side of the woman called the *transferrer*, whose business it is to transfer the pattern from the paper to the biscuit. Taking a biscuit article, she places the several sections of the pattern, with the inked part downwards, in their proper places, and then rubs them in with a roll of flannel firmly tied up into a rubber, one end resting against the hollow of the right arm-pit, and the other upon the biscuit. At first she rubs gently, but afterwards more forcibly, until the ink is fairly transferred from the pattern to the surface of the ware. When a number of articles are thus treated, they are placed in a tub of water, and gently washed with a brush to get rid of the paper.



PRINTING STONE-WARE.

The articles thus prepared are placed in an oven for a few hours, and subjected to a heat sufficient to drive off the oily particles of the ink, and the water imbibed during the washing. The ware is then covered with a glaze, which completely conceals the pattern, but which in the glaze-kiln melts into a transparent glass, completely protecting the pattern but leaving it perfectly distinct.

In some cases another method is adopted for transferring the design to the surface of the ware after glazing. A flexible sheet of glue, called a *paper*, or *bat*, being placed upon a flannel, the engraved plate, charged with oil, is brought down upon it, and gently pressed by hand, when the glue receives an impression of the pattern, which is thence transferred to the surface of the biscuit; being carefully taken off, it is applied to a second vessel, and communicates a second impression. The glue-paper is then cleaned with a wet sponge, and left to dry while other papers are in use. The colour, which is in the form of dry powder, is now dusted over the vessel, and it adheres only to those parts which have received the impression in oil. When the vessels thus treated are put into the oven, the oil is driven off by the heat, while the colour sinks in, and becomes indelibly incorporated with the glaze.

PAINTING AND ORNAMENTING THE WARE.

Earthenware and porcelain are ornamented with various degrees of skill, by artists who lay on the colours with a camel's-hair pencil. The colours are all metallic oxides, and are ground up with certain substances, which vitrify by heat, such as glass, nitre, and borax, in certain proportions. By means of this flux the colours are permanently fixed upon the ware, and are protected from the action of the air and other agencies capable of affecting them. The colours used in painting soft porcelain are those employed for painting in enamel, which is a kind of glass made opaque by oxide of tin, and rendered fusible by oxide of lead. Painting on soft porcelain requires to be several times retouched with the pencil, in order to give it the brilliancy and distinctness obtained by the use of the same colours on hard porcelain, the compact nature of which generally renders these retouchings unnecessary, "except for the most elaborate specimens of the art, which can by such means, however, be produced with the most admirable degree of perfection, so as to render paintings on porcelain not distinguishable from the first productions of the pictorial art, without reference to the body upon which it is performed, or to the means used for bringing out the colours; natural objects, landscapes, portraits, and even historical pictures, being represented with all the truth as well as with all the brilliancy of colouring which distinguished the works of the first masters." *

We do not stop to inquire whether it is quite in good taste to ornament our plates and dishes with landscapes, portraits, and historical pieces. At any rate fashion sanctions the practice, and it is adopted in spite of innumerable difficulties, not the least of which is that the artist has to work with pigments which do not, until they have been fired, at all represent the natural colours of the objects, while the firing is a precarious and difficult art.

It would be useless to transfer to the pages of a work of this kind the various recipes which have been given for coloured enamels and glazes, not only because the reader is not likely to be interested in such details, but also because, in many works, the recipes seem to have been given as much with the view to mislead as to guide. The old artists, who succeeded in producing fine colours on glass and porcelain, kept their processes secret, and when called upon to publish them, did not scruple to give false or insufficient directions. Even at the present day

---

* Porter—Cabinet Cyclopædia.

enamel painters keep the composition of their colours secret; so that in different houses similar results are obtained by slightly different means. It may, however, be interesting to mention what metals are employed for the production of different colours.

Purple and violet are obtained by dissolving gold in aqua regia (a mixture of nitric and hydrochloric acids), and immersing a bar of pure tin in the solution. By this means a precipitate is obtained, named after its inventor, the *purple precipitate of Cassius*. By dissolving the gold and the tin separately, and then mingling them in different proportions, various shades of carmine, violet, and purple are obtained. Other precipitates of gold are also made for the production of these colours.

Red oxide of iron also produces a red colour, of less brilliancy than that obtained from gold. Different proportions of the black and red oxides of iron furnish various shades of reddish brown, chestnut, &c. Oxide of iron, calcined with double its weight of common salt, yields a permanent red colour.

Yellow colours are obtained from chromate of lead; also from white oxide of antimony mixed with sand and oxide of lead. A mixture of the oxides of uranium and lead produces a straw colour.

Blue is furnished by oxide of cobalt; a deep rich shade of this colour to a light blue, is obtained from different proportions of the oxides of tin and zinc.

The green oxide of copper is usually employed in the production of that colour. Various shades are obtained by different mixtures of Prussian blue and chromate of lead. Oxide of chromium also gives a beautiful green colour.

Oxide of manganese is used for black; but it is usual to unite several oxides to produce this colour. A pure white is produced from one part of virgin tin and two parts of common salt.

The colours, when required for use, are pounded in an agate, porcelain, or glass mortar, with a pestle of the same material as the mortar. They are then ground, with a small quantity of oil on a glazed palette firmly bedded in plaster on a wooden frame. The colours are rubbed until all roughness has disappeared. Oil of turpentine is the usual vehicle for the colour and the flux, the proportions of which are carefully weighed out and ground on the palette with the volatile oil. The mixture is made sufficiently fluid for the artist to produce his strokes with the camel's-hair pencil with ease and distinctness. In painting the pattern, he is seated at a table, from which projects a board for the support of his right arm, and he holds the article in his left, as shown in the figure. In most cases, as already noticed, the colour, as applied with the pencil, is very different from its bright creamy and resplendent appearance after the fire has driven off the oil and other matters, which cloud its beauty, and combined the colouring oxide and the flux into a beautiful opaque enamel or transparent glass. It is difficult to imagine that the dark and dingy mixture which seems to disfigure the delicate surface of the porcelain, is capable of so complete a transformation.

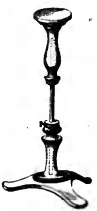
PAINTING PORCELAIN.

When the ware has been painted, the colours are dried, and the oil driven off in a furnace at a moderate heat. They are then glazed, and put into the glaze-kiln, or at once consigned to the enamelling-kiln, as the case may be. It is not necessary to follow this part of the subject further, as the general

Digitized by Google

reader will obtain a sufficient idea of the various processes from the details already given.

The gold employed in gilding porcelain is first dissolved in *aqua regia;* the acid being next driven off by heat, the gold remains in a minutely divided state, and being mixed with borax and gum-water, is applied to the wares with the pencil. Articles which have their edges, or other parts, ornamented with a circular line, are placed on a *whirler,* or circular head of wood, capable of revolving on the top of a pillar. The pillar can be lengthened or shortened, at pleasure, by means of an iron rod inserted within it, and can be fixed to the required height by means of a thumb-screw. The artist, seated in a chair, places this machine before him, and adjusts it to the proper height; he keeps it steady by resting his feet on the claw at the bottom; and fixing the article to be ornamented upon the circular head, he applies the pencil to it with one hand, kept steady by means of a rest, then, with the other hand, he causes the circular head to revolve. In this way circles are described with great truth and readiness. When the articles thus ornamented are baked, the gold appears of a dingy hue; but the beautiful lustre of this metal is brought out by burnishing, first with agate, and then with blood-stone. This is done by a female, who rubs the burnisher lightly on the gilding, taking care not to cross her strokes, lest the gilding should appear scratched. The gilding is cleaned, from time to time, with a little vinegar or white lead, and to prevent the porcelain from being soiled, it is held with a piece of clean linen. It was stated, some years ago, that the weekly con-



sumption of gold for gilding porcelain, &c., in Stoke-upon-Trent borough amounted to the value of 650*l.* sterling, or 35,000*l.* annually.

BURNISHING.

Digitized by Google

THE MANUFACTURE OF ENCAUSTIC TILES.

The revived taste for decoration with encaustic tiles has led to the invention of a number of ingenious processes for the production of those articles, with a facility and beauty of effect which were not capable of being attained by the ancient method. In comparing the old with the modern productions, it may perhaps be said that the former as much excelled the latter in beauty and variety of design, as the latter surpass the former in facility of production, and excellent workmanship.

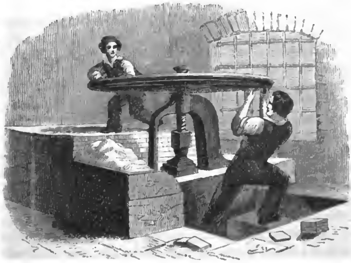
The following account of this branch of manufacture was obtained during a visit to the extensive tile and mosaic works of Messrs. Minton, of Stoke-upon-Trent.

Encaustic tiles consist of a thickness of red clay, with a facing of a finer clay, which bears the coloured ornament or device. The bottom of each tile is also covered with a thin layer of clay, different from the body, in order to prevent warping during the drying and baking.

The body of the tile is formed of red clay or marls obtained from Cobshorst, about four miles from Stoke. When dug out, it is left exposed to the air for about seven months. This is called *weathering* or *wintering*.

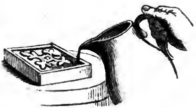
When brought into the manufactory, it is thrown into a tank, and worked about in water with a blunger. When divided to a certain extent, it is laded into another tank, and blunged; this operation is repeated a third time. It is then passed through sieves of various degrees of fineness, mixed with various compositions, and is then either dried into hard lumps and ground into powder at the mill, or evaporated at the slip kiln, according to one of two methods by which it is intended to be formed into tiles.

By Mr. Prosser's patent, the powder, as it comes from the mill, is placed on slabs of plaster-of-paris, slightly damped. It is then sifted through fine sieves, and when subjected to intense pressure, the particles of the powder will unite into firm, solid slabs or tiles. At the lower extremity of the screw of the press, is fixed a steel plate, of the size and pattern of the intended tile; this fits into a steel box of the same dimensions, the bottom surface of which is ribbed, and this, by impressing ribs upon the under surface of the tile, enables it to adhere more strongly to the mortar or cement in laying down the tiles for a pavement, or for covering a wall. A quantity of the powder being swept into this metal box, the steel plate is forced down upon it. In a large press, such

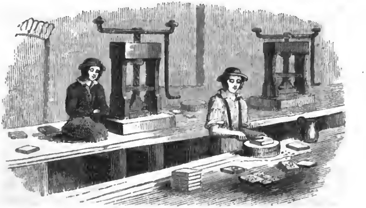

TILE PRESS.

as that shown in the figure, the force exerted is equal to about four hundred tons; and a thickness of three inches of powder is compressed into a tile one inch thick, with sharp edges, and a beautiful polished surface. Tiles of various sizes and shapes are thus produced, the largest of which present a surface of forty-two inches by nine inches; also such articles as tops for tables, eighteen inches in diameter; scale-plates for pork and butter-shops, twelve inches in diameter and upwards. Small ornamental buttons, and shirt-studs, are made in a similar way at smaller presses; also tesseræ, for mosaic work of various shapes, colours, and sizes, forming, when put together, all the beautiful devices of which mosaic work is capable. When, however, the size of a tessera exceeds one and a half inches square, it becomes a tile. When these various articles leave the press, they are put into a hot room for a week or two, and are then ornamented, glazed, and fired.

Such is the method of forming what are called *dry tiles.* Encaustic tiles are formed from the clay after it has been evaporated in the slip kiln. It is wedged and slapped to get out the air, and then slapped into a block, of the form of a cube, or parallelopiped, and placed before the tile-maker, who cuts off and removes a square slab, by passing a wire through it; upon this, the facing of finer clay, coloured so as to form the *ground* of the tile, is batted out, and slapped down; it is then turned over, and a facing is applied to the bottom of the tile, to prevent warping; the tile thus formed is next covered with a piece of felt, and put into a box-press: a plaster-of-paris slab, containing the pattern in relief, is then brought down upon the face of the tile, and impresses in the soft clay, or ground of the tile, the design which is afterwards to be filled up with clay of another colour. When the tile is removed from the press, the name of the maker is stamped on the back, together with a number of holes to make the mortar

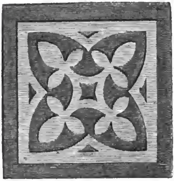


adhere. The filling up of the device is next performed in an ingenious manner. A quantity of slip or clay, in a semifluid state, is poured over the tile so as completely to conceal its surface; this is spread over with a knife, and then left for twenty-four hours, when the slip becomes tolerably hard. The tile is then placed on a small whirler, and the pattern and the ground are brought out by scraping away the superfluous clay and leaving it only in the depression caused by the pattern mould. The whole is, lastly, made smooth, and polished with a knife, and any little defects corrected; the edges are squared and their sharpness rounded off with sand paper; the tiles are then ready for the *green-house*, where they are arranged on shelves, and kept at a moderate heat for about seven days. After this period, the tiles are further dried in a *hot-house*, at a good strong heat;



PRESSING AND SCRAPING TILES.

they are then arranged in seggars, and fired as in baking pottery and porcelain, only about double the time is required for the purpose. The oven is left to cool gradually during about six days, and the tiles are then drawn in their finished state. These tiles contract in firing about one-eighth of an inch in every inch. The dry tiles contract about one sixteenth of an inch.



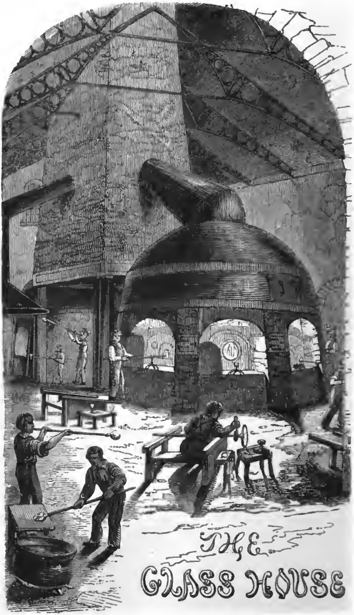
YELLOW ORNAMENT ON BLUE GROUND.

WHITE ORNAMENT ON BLACK GROUND.

STATISTICS.

England has a considerable export trade in earthenware and porcelain, and this has greatly increased of late years. In 1835, the declared value of earthenware exported from the United Kingdom was 540,421*l.*; in 1857 it amounted to 1,492,236*l.*; and in 1858 to 1,150,607*l.* In 1857, the United States of America took British earthenware to the value of 507,267*l.*, so little has the fictile art been cultivated in that country, a defect arising chiefly from the want of suitable raw materials. In the same year Brazil took earthenware to the value of 102,618*l.*; Australia, 141,507*l.*; the East Indies, 56,765*l.*; and British North America 85,102*l.* Our exports are made to most parts of the world, including Russia, Austria, Turkey, and even France, the classic land of the ceramic art. Our exports to foreign countries would be greater, were it not for the duties, and in some cases, the extraordinary modes in which they are calculated. In Germany and Italy the duty is on the weight, irrespective of the quality, a circumstance which enabled Wedgwood, with his new and light wares, to command the market. In France, the duty on common English china of one colour, without gilding or ornament, is 164 francs per 1000 *kilogrammes* (200 lbs.); for fine china 327 francs. In Portugal the duty is charged according to the number of colours, the sense of which is difficult to determine.

Digitized by Google



Digitized by Google

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF GLASS.

It is unnecessary to comment on the value of a substance which is in constant use among all classes of persons, which admits the light of day to the cottage of the peasant as well as to the palace of royalty, and which is daily and hourly employed both for the requirements of scientific investigation, and for the purposes of ordinary life. Perhaps the well-known remarks of Dr. Johnson best and most concisely express the admirable qualities and uses of glass: "It might contribute to dispose us to a kinder regard for the labours of one another, if we were to consider from what unpromising beginnings the most useful productions of art have probably arisen. Who, when he saw the first sand or ashes, by a casual intenseness of heat, melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life, as would, in time, constitute a great part of the happiness of the world? Yet by some such fortuitous liquefaction was mankind taught to procure a body at once, in a high degree, solid and transparent, which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him at one time with the unbounded extent of the material creation, and at another with the endless subordination of animal life; and what is yet of more importance, might supply the decays of nature, and succour old age with subsidiary sight. Thus was the first artificer in glass employed, though without his own knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures; he was enabling the student to contemplate nature, and the beauty to behold herself."

The word glass is said to have been derived from the Latin for ice (*glacies*), on account of its resemblance to pure ice; or from the Gaelic name for amber (*glassum*); or, according to a third conjecture, from an ancient name for woad (*glastum*), on account of the blue tint which it usually exhibited. The origin of the name, and also the origin of the art of making the substance itself, are, however, involved in great obscurity. Pliny's account of the accidental discovery of the art by the Phœnicians, is a very plausible one, and has been generally received. According to this writer, a merchant vessel, laden with nitre or fossil alkali, was driven ashore on the coast of Palestine, near the mouth of the river Belus, a small stream running from the foot of Mount Carmel in Galilee, into the Mediterranean. The mariners, unable to procure stones to rest their cooking vessels upon, used pieces of their cargo instead. The fire reduced the alkali to a soft state, and incorporating with the river sand, it melted down into a vitreous stream. The circumstance was communicated to the inhabitants of the district, who availed themselves of the hint and engaged in the manufacture of glass.

The high antiquity of the art is undoubted; for not only is glass mentioned by a Greek poet, who flourished four hundred and twenty-three years before the Christian era, but Egyptian mummies, of the date of three thousand years ago, are found adorned with beads of earthenware having an external coating of

Digitized by Google

fine glass. Pieces of glass of similar composition have also been found amongst the tombs of Thebes. The glass-houses of Tyre, an ancient Phœnician city on the coast of Syria, are the first of which there is any account; but those of Sidon and of Alexandria afterwards became equally famous. In these early manufactories, articles of mere ornament seem in the first place to have been solely made. Afterwards the art extended to the making of drinking cups and glasses. The high value set on these is proved by the fact that the Roman Emperor Nero gave for two drinking cups of glass, with handles, a sum of money equal to 50,000*l.* sterling. At what time window-glass was first manufactured is not precisely known. It could not have been in use at the time of the destruction of Herculaneum, which took place in the reign of the Emperor Titus, for in that city the windows of the largest houses were made with a species of transparent talc. Perhaps the first mention of glass windows is that of St. Jerome, about the year 422. They are also spoken of by a writer of the commencement of the seventh century, and are described as being fastened in with plaster.

The art of glass-making extended from one kingdom to another, and many cities in succession became celebrated for the manufacture. The glass-manufacturers of Rome had become so numerous in the reign of Alexander Severus, (A. D. 220,) that a principal quarter was assigned to them in the city, and a tax was laid upon them by the emperor. Venice, receiving the knowledge of the art from Rome, became celebrated in its turn; and the artisans of Murano, near that city, attained great skill in making mirrors, which had been previously made of polished metal. But the most celebrated specimen of ancient glass, was the famous Barberini or Portland Vase, lately contained in the British Museum, the wanton destruction of which has caused so much grief and indignation throughout the kingdom. It was found in the tomb

Digitized by Google

of Alexander Severus, (who died in the year 235,) and was formed of deep blue glass, ornamented with white opaque figures most skilfully designed and sculptured in the style of cameos.

The art of glass-making was fostered in France by a decree of the government, early in the fourteenth century, to the effect that none, save gentlemen, or the sons of gentlemen, should engage in any branch of the manufacture, even as working artisans: at the same time a royal charter of incorporation, and various important privileges, rendered the cultivation of this art well worthy the attention of families of distinction, whose capital, thus employed in establishing extensive works, was productive of great national benefit, as well as of a large increase of wealth to their own families. Subsequently the altered state of society naturally led to other and less exclusive regulations.

In England, it is averred by some writers, the art was known even in the time of the Druids. This is supposed to be proved by the coloured glass beads and amulets found among Druidical remains in this country. There seems little doubt, however, that these ornaments were procured by the ancient Britons from the Syrian adventurers, who visited these islands for the purpose of carrying on a traffic with the savage inhabitants. Beads and trinkets are always found attractive to a barbarous race, and are gladly received in exchange for articles of much greater value. Among the most curious trinkets found in barrows or tumuli, are the Druidical glass rings called Glain Nerdyr. These are generally about half as wide as our finger-rings, but much thicker; and it appears that they were employed by the Druids as charms, whereby they might deceive the ignorant. These rings are usually of a green colour, but some are blue, and others variegated with wavy streaks of blue, red, and white. Many of the amulets, &c. above referred to, are of exquisite workmanship, and could not have been the production of an uncivilized nation.

Although there are no means of determining when glass was first manufactured in England, yet so early as the commencement of the fifteenth century allusions are made to the English manufacture. In a contract, dated 1439, between John Prudde of Westminster, glazier, and the Countess of Warwick, respecting the embellishment of her husband's tomb, the said Prudde is bound to use "no glass of England, but glass from beyond the sea." The manufacture of flint-glass was begun in London, at Savoy House in the Strand, and in Crutched Friars, in the year 1557; and the first plate-glass for mirrors, coach-windows, &c. was made at Lambeth, in 1673, by Venetian artists, brought over by the second duke of Buckingham. A century later, an establishment of great magnitude was undertaken by a body of gentlemen, who obtained a royal charter of incorporation, and were styled "The Governor and Company of British Cast Plate-Glass Manufacturers." They commenced proceedings at Ravenhead, near Prescot, in Lancashire; and unto the present day the company is still flourishing.

Religious edifices in England appear to have been first supplied with glass windows in the year 674, when, according to Bede, some continental workmen were brought over by Abbot Benedict, for the purpose of glazing the church and monastery of Wearmouth. For many centuries afterwards, the use of window-glass was confined to ecclesiastical buildings; so that, even at the close of the twelfth century, the windows of private houses were filled with oil-paper, or wooden lattices. Crown, or window-glass, was manufactured at Crutched Friars in London, in 1557.

The manufacture of glass was introduced into Scotland in the reign of James the Sixth, who granted permission to George Hay to manufacture glass, within the kingdom, for thirty-one years. The

Digitized by Google

first glass manufactory was erected at Wemyss in Fife; but larger and more complete establishments were afterwards built at Prestonpans and Leith.

It is somewhat remarkable that the Eastern nations, notwithstanding their ingenuity and skill in many respects, have made very little progress in this important manufacture. Glass-working is practised in China, but it is merely the re-manufacture of old or broken glass of foreign make, which is melted and moulded into new forms. Until Europeans settled amongst them, the Hindoos only knew enough of this manufacture to make beads and trinkets. Before that period there was not a house throughout India furnished with glass windows; and so ignorant were the Hindoos of the optical purposes to which glass might be applied, that they were "astonished and confounded at the effects of a common spy-glass."

MATERIALS OF THE MANUFACTURE.

Glass, in the ordinary acceptation of the word, is a substance composed of silex and an alkali. Under the influence of a great heat, these two substances unite together and form a fluid transparent compound, capable of being drawn out into the finest threads, moulded into articles of use and beauty, or spread out into sheets for glazing our windows, or adorning our apartments. The use of the alkali seems to be to make the silex soluble; it is, however, uncertain whether glass is really a solution of silex in an alkali, or of an alkali in silex.

Five distinct qualities of glass are manufactured for domestic purposes; viz.—

1.—Flint, or crystal glass.
2.—Plate-glass, or glass of pure soda.
3.—Crown-glass, or best window-glass.
4.—Broad-glass, a coarse window-glass.
5.—Bottle, or coarse green glass.

The two ingredients necessary to the formation of all these varieties of glass, are silex and an alkali; the different qualities of glass depending upon the purity of the materials employed, as also upon the addition of other materials, such as nitre, oxide of lead, black oxide of manganese, white oxide of arsenic, borax, and lime.

Silex is abundantly distributed throughout the mineral world: flint is almost entirely composed of it, and this substance being used in the manufacture, gave to flint-glass its distinctive name. But the most convenient source of silex for the glass-maker, is sea sand, which requires scarcely any other preparation than careful washing. For the finer descriptions of ware it is necessary to use the fine white sand usually obtained from Lynn in Norfolk, or from Alum Bay in the Isle of Wight.

The alkalies employed in making glass are the carbonates of soda or of potash. During the progress of the manufacture the carbonic acid of these salts is dissipated, while the alkali and the silex unite together. For flint-glass, pearlash, which is a purer form of potash, is selected, and this is subjected to a further purifying process before it is fit for use. For the coarser kinds of glass, barilla, kelp, or wood ashes, are used, which contain many impurities; among which may be mentioned a variable quantity of iron, the effect of which is to impart a greenish tinge to glass. To the other materials is added a small portion of nitre, the oxygen of which allows the combustion and consequent dissipation of any carbonaceous matter which may be present among the other ingredients.

Oxide of lead, in the form either of litharge or minium, is used largely in making flint glass. Its uses are many; it acts as a powerful flux to the other materials, enabling them to vitrify at comparatively low temperatures; it also increases the density of the glass, and imparts to it greater tenacity when red hot, for which reason it can be more easily worked; and it also enables the glass to resist sudden changes of temperature. It has, however, its defects, especially when used in large proportions; the glass then is so soft that it is easily scratched and injured; it becomes corroded by many acrid fluids, and the glass is not of uniform density, that at the bottom of the pot containing a larger proportion of litharge, and being consequently heavier than the upper portions: the effect of this is to give a wavy appearance to the glass, which is highly objectionable, especially in optical instruments.

Black oxide of manganese (or *glass soap,* as it is sometimes called) is used to get rid of any colour which the impurity of the materials may have imparted to the glass, especially the green tinge, which indicates the presence of iron. The action of this substance is exceedingly curious. When added to glass it imparts a purple colour, which becomes nearly black, according to the quantity employed. If while the coloured mass is in a state of fusion, white arsenic, charcoal, or other carbonaceous matter be added, an effervescence takes place, the colour gradually disappears, and the glass becomes colourless and transparent. The manganese also assists the fusion of the earthy materials, and increases the density of the glass; but it is liable to the same objection as the oxide of lead, that of settling to the bottom of the pot, and giving unequal density to the glass.

Arsenic is used not only to correct the colour of the manganese, but as a flux: it is also of use to dissipate any carbonaceous matter which may exist among the materials.

The use of borax is chiefly confined to plate-glass; it enables the liquid mass to flow with freedom, whereby specks and bubbles, which would impair the beauty of the plate, are avoided.

Lime is a cheap and useful flux, requiring however to be used sparingly, as it otherwise imparts a cloudy appearance to the glass, and corrodes the pots in which the materials are fused.

PREPARATION OF THE MATERIALS.—THE FURNACES AND GLASS-POTS.

The proportions in which the materials are mixed, differ according to the kind of glass to be made; they also differ in different glass-houses for the same kind of glass. The ingredients are mixed in large wooden troughs or boxes, and then undergo a calcination previous to their more perfect fusion in the glass-house. This process is called *fritting*, and the calcined materials *frit*. The chief object of the process is to effect a chemical union between the ingredients at a moderate heat; otherwise the intense heat of the furnace would dissipate the alkali in vapour before it had time to unite with the silex. Other uses of fritting are to drive off all moisture and carbonic acid from the materials, to prevent them from swelling up in the pots, and to destroy all carbonaceous matters that may be present.

The fritting furnace, called *calcar*, is an oven about ten feet long, seven feet wide, and two feet high. The flame is made to reverberate from the crown of the furnace back to the frit. The temperature is gradually raised until the materials have fused into a pasty mass, in which state they are maintained three or four days. The frit is then removed, and before it has time to solidify it is cut into square cakes, and stored up for future use. In this state it is a brittle, crumbling substance, not unlike alum in appearance. According to some manufacturers frit improves in quality by being kept a long time.

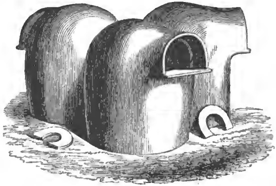
The construction of a glass furnace is of considerable importance; for it has to maintain the glass pots at an intense heat capable of melting the frit, but at the same time it should not be liable to destruction. Clay is the chief material used in the walls of the furnace and in the pots. The clay is mixed with a portion of sand, sufficient to make it work easily, to dry into a compact mass, and to resist the action of the fire for a length of time. Too much sand renders the clay liable to vitrify and separate from the walls. The external form of the furnace is usually that of a huge cone rising from a circular base, and terminating in the chimney. The form of the interior is that of a dome supported upon arches. Below these are flues for the admission of air, which rising through the bars which occupy the centre of the floor of the furnace, the flame and heated air surround the pots, and thence enter the chimney from the centre of the dome.

The crucibles, or glass-pots, in which the frit is melted, are made to vary in size according to the objects of the manufacturer; each pot is sometimes large enough to contain a ton of glass; although from fourteen to sixteen hundredweight is the more usual capacity. Twelve of these pots are usually placed in the circumference of each furnace, the mouth of each pot passing into an opening made in the wall of the kiln; so that the pots can be readily charged and their contents withdrawn by the workmen, who stand in recesses formed by projections of the masonry.

The arrangements of the furnace in Messrs. Pellatt's glass-house (represented in the frontispiece) differ somewhat from the above description. Instead of one large twelve-pot furnace, two smaller ones are in use; these contain the same number of pots as the large furnace formerly employed; but the internal area of the two being together equal to only one-half that of the old furnace, the pots are necessarily brought more within the influence of the fire. The same chimney is made to serve for both furnaces. It is supported at the four corners upon massive pillars, so that each furnace has an open space all round it. It is not, however, necessary to work both furnaces at once; nor is this done except when trade is unusually brisk. It is said, that by means of this alteration the weekly expenditure of coals has been lessened to the extent of ten chaldrons.

Digitized by Google

The crucibles, or glass-pots, are made at the glass-house, and are the subjects of great anxiety and care on the part of the manufacturer, as on their stability much of the success of his operations depends. They are usually made with five parts of Stourbridge fine clay, and one part of old broken crucibles ground to powder. They are manufactured in the winter season only, in order that they may not dry too rapidly. The clay is kneaded by the workman with his naked feet; he turns it over and over, and subjects every part to pressure—the object being to produce a consistent, equable mass, entirely free from air bubbles; for these, by their expansion in the furnace, would cause the fracture of the pot. The attempts to substitute machinery for the naked feet of the workmen in kneading the clay, have entirely failed.



GLASS-POTS.

A moderately sized melting-pot holds about fourteen hundredweight of glass: its appearance may be judged of by the accompanying figures better than by description. It is cylindrical in shape, with a domed top and a flat base; and has an opening near the top of the cylinder. The highest is about two feet, the diameter two and three quarter feet, and the clay from two to three inches thick. These pots are built up with rolls of the well-kneaded clay, care being taken to exclude every particle of air from between the rolls, and to form every part of the vessel of uniform thickness. The potter usually completes four pots in a week, working a little at each pot every day.

The pots are allowed to remain during several months in the room where they are made, in order to part with their moisture, and to solidify in an equable manner. During this time the temperature of the room is gradually raised. When a new pot is required in the furnace, it is first annealed, in order to prepare it for the intense heat to which it is about to be exposed. The annealing furnace is a sort of room, or oven, on a level with the floor of the glass-house, and capable of holding several pots. Flame from an adjacent furnace is made to reverberate into it, and thus the pots are gradually brought to a red and then to a white heat, and are maintained at this during a few days. The pot is lifted out of the oven while in this heated state, and set in the furnace without being allowed to cool, or causing any diminution of the heat of the furnace. The reader will, therefore, readily suppose that the "setting a new pot" is one of the most tremendous operations of the glass-house.

Through the kindness of Mr. Pellatt, the writer was present during one of these operations. The first part of the process was to get out the old pot, which had done duty for seven months, but was now rendered worthless from having "sprung a leak." The heat of the glass-furnace is sufficiently intense to an unpractised looker-on during the ordinary operations of glass-blowing, &c., when the fire is covered up by badly conducting materials, with the exception of a few apertures for getting out the glass, and heating the tools, &c.; but now the wall of one of the arches was to be taken down, thus exposing the men to the naked heat of a huge furnace. The men were about twenty-four in number, two or three of whom worked at a time, and were frequently relieved.

The difficulty of getting out the old pot was very great, owing to the firm hold which it had on the floor of the furnace: it was, in fact, cemented to the floor by the glass which escaped from the crack whereby it was rendered useless; and this cementing glass became more and more difficult to loosen, as the current of air, which rushed towards the now large opening, solidified the glass. The men, therefore, had to work at the bottom of the crucible with huge crow-bars, resting upon a little roller, supported upon an iron frame, placed at the mouth of the opening. The blows of the crow-bars brought away large pieces of glass, soiled and blackened by the ashes of the furnace, fire bricks, masses of clay, and sometimes pieces of the pot itself. The crow-bar was held by two or three men, who gave a few blows, and then retreated from the fierce heat, to be succeeded by two or three others, who, in like manner, performed their minute's work, and retreated to the shelter furnished by the massive wall of the furnace.

At length the pot being loosened all round, its base was elevated by crow-bars, and a low iron truck moving on two wheels thrust under it; and thus it was withdrawn and thrown aside at some distance. The floods of heat which now radiated from the opening were terrible; the side of the pot nearest the opening, by its contact with the air, had cooled somewhat, and served, to some extent, to keep off the full glare of the furnace; but now there was no shield—no defence. And here was, perhaps, the most arduous part of the operation; the floor of the furnace had to be prepared to receive the new pot: for this purpose the most fire-proof workman was selected; he was furnished with a kind of shovel, with a handle fourteen or fifteen feet long, resting on the roller before noticed. A number of men stood by, each holding a large kneaded piece of fire-clay—one of them, as he was directed, went up to the mouth of the opening, and placing his piece of clay on the shovel, quickly retreated. The clay was then deposited on the bed of the furnace, and worked quickly with the spade; and thus piece after piece was deposited until a tolerably even bed was produced. Another party of men then went with the iron truck to the annealing oven; its folding doors being thrown open, revealed the pots, now mounted at about a yard from the floor, glowing at a bright red heat. To thrust in the truck under one of them and bring it out, was the work of a moment; it was quickly wheeled to the furnace; deposited in its place, and being held by crow-bars, the truck was drawn out from under it: the whole being accomplished with a dexterous celerity which pleased and satisfied the looker on.

The next part of the operation was to close up the opening, for which purpose two heated masks of fire-clay were brought on shovels; these rose from the ground about a yard high; upon them were placed bricks and fire-clay. The mouth of the pot being closed with a temporary screen of clay, the rest of the opening was closed up with great despatch by a number of men, each bearing a portion of clay or a brick, which he knew precisely where to deposit.

The new pot having safely undergone all these severe tests, has to be proved by a yet more arduous one. Will it hold glass? is the anxious inquiry of the manufacturer. When the proper temperature has been regained, it is loaded with frit, and watched every hour until the workmen are again ready to help themselves from its contents. The surface is watched to see that it does not fall; for if it does, there is a crack, and the glass is leaking away. Should this be the case, the wall of the arch is again hastily pulled down; cold air is admitted; the glass about the crack solidifies, and thus the contents of the pot (often from sixteen to twenty hundredweight of glass) are saved.

The arrangements with respect to the working hours in a glass-house are somewhat peculiar. The

Digitized by Google

intense heat required to melt the glass renders it necessary always to maintain the furnace in a vivid state of combustion; for if once suffered to go out, or to cool down, there would be great loss of time and fuel in getting up the heat again. When the pots are filled with fresh materials for flint-glass, about forty-eight hours are required to bring them into a proper working form; the supply of *metal* (as the molten glass is called) is therefore proportionate to the demands of the manufactory during the first four working days of the week: the men working incessantly night and day in sets, which relieve each other every six hours. By Friday morning the pots are so far emptied as to require re-filling, which being done, the fire is urged briskly; the pots are repeatedly watched and skimmed, and portions taken out from time to time to test the quality of the metal, so that by Monday morning every thing is ready for the usual operations of the glass-house. It is to be regretted that the long-continued application of heat to the glass-pots renders it necessary to employ some of the men on Sunday; but as the whole of their duty on that day is simply to watch the furnace, it is so arranged that the attendance of each workman one Sunday in every four is all that is required.

In the manufacture of flint-glass, the materials, being in a state of considerable purity, are not always fritted; but being intimately mixed, are cast, by means of clean iron shovels, into the pots when at a clear white heat. When the materials have melted down, the operation is repeated until the pot is full of the molten metal. The mouth of the crucible is stopped up with clay, in order to confine the heat, a narrow opening being left, through which the contents may be examined, and impurities removed.

The materials do not at once melt into a clear limpid glass: they acquire their transparency by slow degrees, as a white porous scum rises to the surface of the mass, and is skimmed off. This scum is called *sandiver*, or *glass gall*, and consists chiefly of impurities existing in the alkali, which having no affinity for silex, and being lighter than the melted glass, rise to the surface, and, unless removed, would soon disperse in vapour, and corode the top of the crucible. Another portion of sandiver, consisting of vitrified metallic and earthy impurities, is sometimes found at the bottom of the pots, and is removed before the pots are refilled. Sandiver is sold to the refiners of metals, who find it useful as a powerful flux. If the sandiver were allowed to remain in the glass, articles formed of it would be cloudy and full of bubbles. By a long continuance of the heat this substance is got rid of, and other impurities are also removed. The glass increases in flexibility and weight, and becomes colourless and translucent. To those who have the courage to look into the furnace, the pot of glass is a very beautiful sight; but the very attempt to view it is painful, from the intense heat. But if the spectator is furnished with a square of glass set in a wooden frame, he will find this to be a very effectual screen from the heat, enabling him to witness all the operations of the glass-house (even the setting of a new pot) with little comparative

MOUTH OF THE FURNACE.

inconvenience. The writer found, that by wearing spectacles he could look into the furnace, which, with the unguarded eye, it was impossible to do.

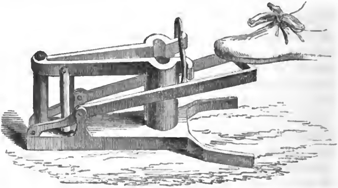
When the materials are thoroughly vitrified, the mass is in too fluid a state to be worked. The temperature of the glass-pot is, therefore, somewhat lowered by stopping the draught of the furnace in that part where the crucible is placed; the clay with which its mouth was partially closed is removed, and the glass-blower can now commence his operations. During the time employed in working a pot of glass, which varies from five to twenty hours, or longer, its consistence should be maintained at about the same point; this, therefore, calls for much attention on the part of the workmen. As the glass may be kept in a melted state without injury, it is usual to work up the contents of two or three of the pots before the others are touched.

MANUFACTURE OF ARTICLES IN FLINT-GLASS.

The various articles of use or beauty which are made of flint-glass, are, for the most part, produced by blowing the melted glass into form, and moulding it by hand, with the assistance of a few simple tools.

The chief implement of the glass-blower is a hollow iron tube, or rod, four or five feet long, and about one-eighth of an inch bore, and technically called *the iron*. By dipping one end of this tube into the pot, and turning it about several times, the workman collects upon it a quantity of melted glass sufficient to form the intended article.

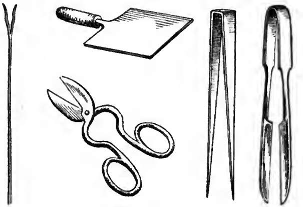
On one occasion, when the writer visited the glass-house, a set of men were engaged in making eight-ounce phials. Having collected upon the iron a quantity sufficient for making one phial, (which is judged of very accurately by the eye,) the man held the rod vertically for a moment, and gave it a slight jerk, the effect of which was to lengthen out the glass beyond the rod: he then rolled the red-hot lump upon a smooth table of iron, in order to give it consistency and form; pinched the upper part of it with pliers, in order to form the neck; then placing the glass in a brass mould, (the two halves of which were brought together by pressing on a pedal,) he blew down the tube, the effect of which was to hollow out the glass and make it fill up the mould, the form of which it, of


FLINT-GLASS BOTTLE MOULD.

MAKING BOTTLES.

course, immediately assumed. On removing his foot from the pedal, the mould fell asunder, and a phial was seen adhering to the tube; it was detached by contact with a piece of cold iron; then taken up on the end of a heated rod by another workman, who softening the bottle at the mouth of the furnace, touched it up and finished it off with great rapidity; it was then conveyed by a boy to the annealing oven. The same mould was used by two blowers, one of whom was collecting and rolling his glass, while the other was blowing it out. Probably not more than a minute was consumed about each bottle.

In another part of the glass-house, a superior set of men were engaged in making oval preparation-glasses. A quantity of glass having been collected at the end of the iron, it was rolled out, and then blown into a pear-shaped form; the man then swung it round in a gentle whirl, the effect of which was to elongate it into a nearly cylindrical form. It was then given to a man seated in a sort of arm-chair, who, placing the tube upon the chair arms, rolled it backwards and forwards. By means of a scale and compasses, he ascertained whether the cylinder was of the proper size; the first man then collected a quantity of melted glass upon an iron rod, called a *punt* or *pontil*,—which is a solid iron rod, smaller and lighter than the tube used for blowing,—and handed it to the man in the chair, who, pinching a portion of it, detached a large lump, and allowed it to fall upon the lower end of the cylinder, to which it instantly adhered, and formed the bottom of the vessel. He then took a flat piece of wood from a bucket of water, and pressed it against the lump of red-hot glass, rolling the tube all the time: the effect of which was to spread out the glass into a flat surface or base. By this time the glass had cooled below the working heat; the man therefore held it in the mouth of the glass-pot, turning it round all the time, until it was again softened: on withdrawing it, he resumed his seat in the arm-chair, and pressing the two opposite sides of the cylinder against the *marver*, (as the flat iron table is called,) the cylinder was converted into an oval: he again placed the tube on the arm-chair, when a boy stooped down, and blew through it, the effect of which was to distend the glass to the proper dimensions. Great care is required in regulating these operations, in order that the vessel may be of the proper dimensions: the compasses and scale are frequently applied, as also an iron instrument, formed something like a pair of sugar-tongs, with which the vessel is moulded to the required dimensions.



GLASS-BLOWER'S TOOLS.

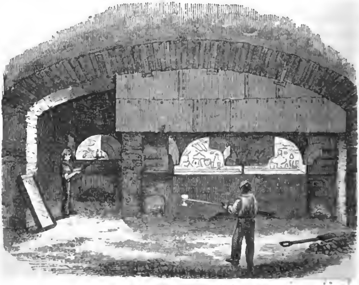
The oval being properly formed, and its base or foot being worked to the requisite shape, the vessel was now transferred to the punt; for which purpose a boy having collected a small quantity of melted glass at one end, applied it to the centre of the base of the vessel, where it adhered firmly: the end attached to the iron tube was easily separated from it, by touching it with a small piece of wet or cold iron. Another workman now took the vessel mounted on the punt, and proceeded to fashion the mouth and upper parts of the article: he first softened it at the furnace, then opened the mouth, and cut away any superabundant material with scissors, with as much ease as he could divide a piece of soft leather. If the vessel was not long enough, he swung it to and fro, and dexterously whirled it in a circle through the air, whereby the soft red-hot glass easily yielded to the centrifugal force, and was elongated. He then sat in the chair, and rolling the tube to and fro, finished it according to the required pattern, turning over a portion of the glass to form the upper rim; bending it to form a lip, and constantly testing the progress of his work by his scale and compasses.

GLASS-BLOWER AT WORK.

It is not easy to impart to the reader the admiration excited in the spectator at the sight of the simple and beautiful operations, on a material which we are accustomed to consider so fragile and unyielding. It is indeed interesting to witness the ease and skill with which the workman rolls and pulls, whirls, divides, and joins the plastic material, whereby he rapidly converts a glowing lump of shapeless matter into a useful and elegant article.

The moment the article is finished, it is detached from the punt into a wooden shovel, and immediately conveyed by a boy to the annealing oven. It is still very hot, and requires to be cooled gradually. Without this, it would be liable to crack at every change of temperature, and a scratch, or even a touch, would often be sufficient to destroy it.

The annealing oven, or lier, is a long, low-arched chamber, heated at the end which opens into the glass-house, and furnished with shallow iron trays, called *lier-pans*, or *fraiches*, which can be pushed along the level bottom of the chamber. Newly made articles are first placed on these trays, in the hottest part of the oven; as the trays are filled, they are pushed forward towards the cooler end, where they are taken out after the lapse of many hours, at a temperature not much above that of the atmosphere. The articles being thus gradually allowed to part with their heat, they contract into a uniform and consistent substance. The time allowed for annealing varies with the bulk of the articles: those which are thin require only a few hours' exposure: large and thick articles require a longer time, and a greater heat when first placed in the oven.



THE ANNEALING OVEN.

MANUFACTURE OF CROWN-GLASS.

CROWN-GLASS, or that used for windows, is required to be much harder than flint-glass, in order to resist the action of the weather. On this account, no lead or metallic oxide is used in its preparation; and as it cannot therefore be so readily fashioned in a variety of shapes, the principal demand is for those enormous discs, the halves of which may be seen in the glazier's crates.

The materials of crown glass, as of the other descriptions of glass, differ slightly in their nature and proportions in different manufactories. Sand and soda are the essential ingredients, to which are sometimes added minute portions of borax, arsenic, and manganese; and a large proportion of *cullet*, or broken crown-glass, is subsequently added. The materials are first fritted in a large reverberating furnace, the mixture being well worked together with iron paddles, shovels, and rakes, with long handles. In about four hours the fritting is complete. The founding-pots are then filled up with blocks of frit, and the furnace is powerfully urged by opening all the subterranean passages to its grate. In about eight or ten hours a fresh charge of frit can be added. In sixteen hours vitrification has taken place, and a large quantity of sandiver is floating over the surface. This being skimmed off, the pot is ready to receive its *topping* of cullet, which is shovelled in at short intervals. The heat is still continued during some hours; more sandiver is skimmed off; and as the fusion proceeds, a quantity of gas, called the *boil*, is given off. At the end of about forty hours from first charging the pots, the glass is again carefully skimmed, and the working of the pots commences.

It should be remarked that the arrangement of a crown-glass furnace differs in some particulars from that used for flint-glass; but we need not pause to detail these. The glass-pots, too, are cylindrical in shape, without any hood or cover.

The workman having collected a quantity of molten glass at the end of his rod, by dipping it repeatedly into the crucible, sufficient to form a sheet of glass, which generally weighs from ten to eleven pounds, rolls it on the iron plate before noticed, and then blows it out into a pear-shape, taking care that the air within the cavity is surrounded with an equal body of glass, and correcting any inequality by rolling it on the marver. He now heats the bulb in the fire, so as to form the glass at the end of the tube, and by a dexterous swing lengthens out the bulb. To extend the neck of the pear, he rolls it over a smooth iron rod, and then flattens the end opposite to the tube by pressure against a plane surface. A small portion of melted glass is then collected at the end of a punt, and is applied to the centre of this flattened part: the hollow tube is then removed by wetting the glass, leaving a circular hole about two inches in diameter. The glass is next carried to an opening in the furnace, called the *bottoming hole,* where it is exposed to the action of flame. A slight wall erected before one half of this hole screens the workman from the heat, but leaves room for working the glass. The man begins to twirl the punt slowly at first, then more and more rapidly; the glass yields to the centrifugal force; its diameter becomes greater and greater; the hole left by the removal of the tube expands proportionately, until at length the doubled portion flies open, and the glass is converted into a plane disc, four or five feet in diameter; of uniform thickness throughout, except at the point where it is attached to the iron rod, where there is a lump called the *bull's eye.* The plate is then removed to the annealing oven, and placed on its edge.

Crown-glass is sold in *crates,* or *sides,* consisting each of twelve of the discs just described. It is sold,

Digitized by Google

according to its quality, as *firsts, seconds, thirds,* and *fourths:* the fourth quality producing a price about one-half that of the first. These variations depend for the most part upon the temperature of the furnace, which being once suffered to fall, it becomes very difficult to raise it again, on account of glass being so very imperfect a conductor of heat. In a large glass-house the greater proportion of glass usually consists of seconds and thirds; about one-third of the quantity is of the first quality, and it very seldom descends to fourths.

Broad-glass is a coarser description of window-glass, made of inferior materials, and by a process somewhat different from that just described, but sufficiently similar to render a description unnecessary.

The fact may, perhaps, excite surprise, that the principal part of the manufacture of glass in Great Britain consists of common green bottle-glass. In the year 1840, duty was levied upon no less than 26,286 tons of bottle-glass, while the total quantity of all the other descriptions of glass, during the same year, was only 14,720 tons. To account for this enormous demand, it may be stated that not only are bottles made of this kind of glass, but a variety of articles useful in the chemical and other arts: such as retorts, subliming vessels, tubes, and carboys; this kind of glass resisting the action of heat and of corrosive liquids much better than flint-glass; a quality which is due, in great measure, to the coarseness of the materials employed in the manufacture, which requiring an intense heat for their fusion, and the fluxing materials being of an earthy nature, the resulting glass is exceedingly hard and durable.

The manufacturers of this kind of glass have hitherto been restricted to the use of the commonest sea or river sand, lest the revenue should suffer by bottle-glass becoming the successful rival of flint-glass, which paid about eight times the amount of duty; but now that the duties on every kind of glass are

Digitized by Google

repealed, the manufacturer is at liberty to introduce any and what improvements he may please; and, doubtless, a marked improvement will be noticed in this branch of the manufacture. It is, therefore, partly for this reason that we do not describe processes which may soon cease to be practised, and also because the usual method of making bottles does not greatly differ from that already described for phials of flint-glass.

MANUFACTURE OF PLATE-GLASS.

In the manufacture of plate-glass it is of the utmost importance to select such materials as will fuse into a freely flowing liquid, because in casting large plates, this quality of flowing freely is necessary to ensure the absence of streaks or bubbles. In this respect soda is found to be preferable to potash; the sand must be of the finest and whitest kind. Lime is also added, for assisting the fusibility of the silex and alkali. Manganese and oxide of cobalt are used as decolouring substances, the action of which is very remarkable: the effect of the manganese is to impart a red tinge, but when mixed in proper proportion with the blue of the cobalt, and the natural yellow tinge of the other materials, the three colours (which are the primary colours constituting white light) combine, leaving the glass colourless.

In preparing the fresh materials, a considerable quantity of pounded fragments of glass is used. There is always a supply of this material produced from what is spilt in casting, and from the ends and edges cut off in shaping the plates.

The proportion in which these materials are mixed varies at different plate-glass works; but, according to Mr. Parkes, the following proportions produce plates of the best quality. The quantities indicated will produce one pot of metal, equal to 1,200 pounds of good plate-glass.

Lynn sand, previously well washed and dried,	720 parts.
Alkaline salt, containing 40 per cent. of soda,	450
Lime, slaked and sifted	80
Nitre	25
Cullet	425
	1700

The sand, lime, soda, and manganese, being mixed with the greatest care, are fritted in small furnaces during six hours, the materials being carefully stirred so long as vapour is given off, and until the materials sink down into a quiet homogeneous mass. The cobalt and broken glass are then added.

The frit requires an exposure of nearly forty hours to a strong heat, before the glass is ready to be cast. When the glass is properly refined, it is gradually removed, by means of a copper ladle, from the glass-pot into a smaller crucible, called a *cuvette*, which stands empty in the furnace exposed to the full degree of its heat. The size of the crucible is made to vary according to the dimensions of the plates intended to be cast. The proper quantity of glass being collected, the cuvette is allowed to remain some hours in the furnace, to get rid of air bubbles. Samples are taken out from time to time, in order to judge of the fitness of the glass for casting.

The glass is poured out or cast upon tables with perfectly smooth and level metallic surfaces. The British Plate-Glass Company make use of an iron table, or plate of cast-iron, fifteen feet long, nine wide, and six inches thick. Its weight is nearly fourteen tons; it is supported on castors, and moved about to the mouths of the different annealing ovens, as occasion requires.

The glass-foundry at Ravenhead was till lately the largest room, under one roof, that has ever yet been erected in this kingdom; its dimensions being 339 feet by 155 feet, and height in proportion.* The melting furnaces are ranged down the centre; the annealing ovens are on each side of the foundry, each oven being 16 feet wide, and 40 feet deep; their floors are on a level with the surface of the casting table, so that the plates of glass are quickly and easily removed from it into the ovens.

The melted glass in the cuvette being in a fit state for casting, this crucible is lifted out of the furnace by means of a crane, and being placed on a low carriage it is conveyed to the casting table, which stands as near as possible to the annealing oven destined to receive the plate. The utmost care is taken to prevent any dust or dirt, or scum, from mingling with the glass; the outside of the cuvette is cleaned, and the surface of the glass is skimmed. The cuvette is then clasped by pliers, and being wound up to a sufficient height, it is turned over and moved quickly across the table, depositing the glass in an equable manner. "The spectacle of such a vast body of melted glass formed at once from an immense crucible, on a metallic table of great magnitude, is truly grand; and the variety of colours which the plate exhibits immediately after the roller has passed over it, renders this an operation far more splendid and interesting than can possibly be described."

The thickness of the plate is regulated by ribs of metal placed along the whole length of each side. A rib is also held at the lower end of the table. A large copper roller, made perfectly true and smooth, extending across the table, and resting on the side ribs, is then set in motion, and the glass, during its progress, is rolled out into a sheet of uniform breadth and thickness.

During the whole of this process it is necessary to keep the apartment as free from disturbance as possible, lest the surface of the glass be disturbed, and the plate impaired in value. As soon as the glass is set, it is carefully inspected, and should any flaws or bubbles appear, the plate is divided by cutting through them. It is then slipped from the table into the annealing oven, where it is allowed to remain during about fifteen days in a horizontal position, the heat of the oven being gradually reduced until the plate is cold.

---

* Marshall's flax-mill at Leeds, erected about four years ago, is about 400 feet by 216 feet.

The plate is then taken out and squared, by cutting off the edges with a diamond, guided by a square rule. It is next removed to the grinding apartment, where it is imbedded in plaster of Paris upon a table; and a similar plate being imbedded in a frame, the two glass surfaces are rubbed together, a mixture of flint-powder and water being interposed. When one side is sufficiently ground it is turned over, so as to present the other surface, to be ground in the same manner. In this process a certain amount of pressure is required, and as the grinding proceeds, the upper plate is loaded with weights.

The effect of this grinding is to remove all inequalities from the surfaces, but they are, as yet, too rough to be polished; they are therefore again ground with emery powder of increasing degrees of fineness, the effect of which is to make them perfectly smooth and even, although opaque or deadened. The plates are again rigidly examined, and should any flaws or defects appear, they are cut up into smaller plates, so as to leave the blemishes at their edges. It is important to divide the plate into as few pieces as possible, since the value of many small plates is not to be compared with that of one plate equal to them all in area.

The plates are polished with the brown red oxide of iron,—known in the arts as *crocus*, or *colcothar*,—moistened with water; this is applied by means of a hard elastic woollen cushion, furnished with a handle, and rubbed backwards and forwards over the surface of the plate. This is sometimes done by machinery. Much skill is required to produce a high and, at the same time, a uniform degree of polish on the plate. When both sides are polished, the plate is washed and placed, each side in its turn, upon a dark blue or black cloth, which, by moderating the quantity of light, enables the eye to judge whether the whole surface has been equally polished. If not, the defective parts are retouched by a small polishing cushion.

STATISTICS.

THE glass manufacture has long been a considerable branch of industry, and a source of revenue in this kingdom; and although it has had to contend against the unfettered manufacturers of the continent, yet it has successfully rivalled them, except in some of the ornamental departments. The most costly branch of the art, the manufacture of plate-glass, has made such progress, that English plate-glass is now even preferred to the French; while our flint-glass is superior to any in the world.

Still, however, the demand for glass has not kept pace with the growth of our population, and with our increased means of commanding the conveniences of life. Mr. Porter attributes this deficiency to the high duties which have been imposed on the manufacture, while "the processes of the manufacture have been so interfered with by the regulations necessary to collect those duties, as to prevent the introduction of many improvements;" and, "in order to work profitably under those regulations, it has been necessary to carry on the manufacture upon so large a scale, as to create a virtual monopoly, of some of its branches at least, in the hands of a few — a state of things generally unfriendly to improvement."

Now that the duty is entirely removed from glass, the improvement of the manufacture will, doubtless, proceed at a rate which cannot be calculated; new processes will be invented, and glass will be applied to uses of which we have, as yet, but little conception. Nearly all the materials of which glass is composed, are abundantly produced in this country, and the rest can be procured at as cheap a rate as in any other manufacturing country. The art of the glass-maker is very simple; his implements are few and inexpensive, and it can be prosecuted on a small as well as a large scale. All these encouraging circumstances are most favourable to the rapid improvement of the manufacture. An increased knowledge of the art of design among the operatives, and an extended application of chemistry to the production of colours in glass, would soon enable us to compete successfully with the manufacturers of Bohemia and France.

The choice of the principal seats of any manufacture depends, in great measure, upon the facility with which the raw materials, or the fuel, can be procured. Thus Newcastle and South Shields are the principal seats of the manufacture of crown and bottle-glass, in consequence of the excessive cheapness of small coal, or slack, in that district. The largest manufacture of crown-glass is near Birmingham. Considerable manufactures of flint and of other glass are carried on at Dudley, Stourbridge, Liverpool, Bristol, and Warrington, and to a less extent in Leeds, Manchester, and London. In Scotland the manufacture is principally carried on at Dunbarton, Glasgow, Leith, Haddington, and Ayr. The Irish manufactures are but trifling: the principal seats are Dublin, Cork, Lisburn, and Waterford.

It is difficult to form an estimate of the value of glass manufactured annually in the United Kingdom. Mr. M'Culloch believes it may be taken at about 2,000,000*l.*, and the number of workmen at about 50,000.

The following are the quantities of glass for the United Kingdom, which paid duties for the years 1838, 1839, and 1840:—

GLASS.	1838.	1839.	1840.
	Cwts.	Cwts.	Cwts.
Crown	147,553	136,712	146,838
Flint	98,897	104,955	104,882
Plate	25,813	28,413	33,623
Broad	6,575	8,514	9,051
Bottle	451,419	485,166	525,720

The following are the gross amounts of duty during the same periods:—

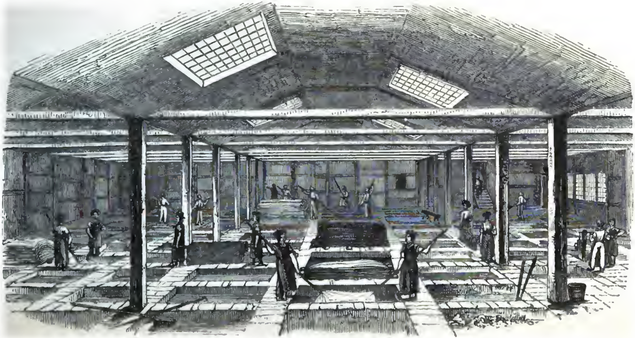
GLASS.	1838.			1839.			1840.		
	£	s.	d.	£	s.	d.	£	s.	d.
Crown. .	542,257	5	6	502,416	12	0	556,951	8	5
Flint . .	92,303	17	2	97,958	0	0	101,035	19	7
Plate . .	77,439	0	0	85,239	0	0	104,119	11	6
Broad . .	9,862	10	0	12,771	0	0	13,916	11	0
Bottle . .	157,996	13	0	169,808	0	0	189,943	4	10

An inquirer into the effects of a particular trade upon the health of the operatives, is very apt to infer evils which really do not exist. Experiencing in his own person the inconveniences of a new situation, he believes that men so circumstanced during a great part of their lives, *must* be effected with serious disorders. The high temperature to which glass-workers are accustomed, does not appear to have any

Digitized by Google

very injurious effect. The ordinary temperature of a glass house is about 70°; but when the men approach the furnace, which they are constantly doing, they are exposed to a heat considerably above 100.° Many of them are generally bathed in perspiration from the effects of heat only, for the muscular labour is very moderate. They are subject to coughs and colds, and in warm weather they describe their employment as being "very weakening." But they seem to be cheerful and contented in their work; and, when temperate in their habits, attain the usual age of man. Many of them are, however, unfortunately addicted to drinking. Mr. Thackrah says that individuals among the most intemperate are known to take, sometimes, as much as two gallons of beer in the day. "A practice like this, though probably less injurious than in occupations where the heat is moderate, produces disorder of the digestive organs." With the exception arising from this habit, the men are in good health.

Digitized by Google



THE TAN PITS.

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF LEATHER.

THE manufacture of leather in this country ranks next in importance to that of cotton, and of wool; and is, perhaps, equal to that of iron. Nor need this excite surprise, for what substitute could be found for leather?—a substance at once durable and elastic; affording protection from wet, from cold, and from external injury; capable of being formed into innumerable useful articles, and susceptible of a high degree of ornament; entering into the structure of various engines and machines; supplying harness to our horses, linings to our carriages, and covers to our books. But the chief importance of leather arises from its value as an article of clothing; and the necessity for such a protection seems to have stimulated man in all ages, and in the most widely separated parts of the globe, to the invention of some method for preserving the skins of animals.

Hence, it is difficult to say anything respecting the origin of an art, which, being so necessary to the comfort and welfare of mankind, must have been practised at a very early period. The skins of beasts taken in the chase are, in their fresh state, tough, flexible, and elastic, and seem well adapted for clothing; but in drying they shrink, become horny, and are liable to putrefy by exposure to moisture. But the qualities of the skin, which adapt it so admirably to the purposes of clothing, may be restored, and even rendered permanent, by placing it in solutions of certain vegetables which abound in almost every country. Skins may also be made incorruptible, by steeping them in mineral waters which contain iron or copper; and the same purpose is answered by rubbing in oil or fat, a practice which is clearly alluded to by Homer.

The object of these processes being to render soft and flexible, that which would otherwise be hard and unyielding, the skin thus transformed was called by our Saxon ancestors, *lith, lithe,* or *lither,* (that is, soft, yielding,) from which the word *leather* is supposed to have been derived. The word to *tan,* and the French *tanner,* are from the low Latin, *tanare.*

VARIETIES OF SKINS USED IN TANNING.

Leather is prepared from the skins of animals by means of a peculiar vegetable substance, found in the bark of most trees, called *tannin.* It is also made by a preparation of alum and salt, as in the process of *tawing;* a third method is, by dressing in oil.

The skin or hide of an animal consists of three distinct parts placed one over the other:—1st, the *epidermis,* or cuticle, which is covered with hair or wool; 2d, the *reticulated,* or *net*-like *tissue;* and 3d, the *dermis,* or true skin, which is in contact with the flesh. This last is the only part which can be tanned; so that it is necessary to get rid of the two former before the process of making leather can be commenced. The true skin is a thick, dense, hard membrane, composed of fibres interlacing each other in a curious complex manner. It is not equally thick throughout its texture; the part which covers the mane, the back, and the rump, being much thicker than the parts covering the belly. This skin consists, chiefly, of a substance called *gelatine,* from its jelly-like appearance when in solution: it is an abundant material in many animal matters; in the skin of the ox it is indurated, that is, hard. Gelatine is distinguished from albumen (of which the white of an egg chiefly consists), by being easily dissolved in warm water; whereas albumen is made solid by heat. All animal matter which affords gelatine may be used in making glue.

It might be supposed, in consequence of the vast quantity of animal food consumed in England, that the shambles would afford an abundant supply of skins to the tan-yard; but the hides furnished by this country are by no means sufficient in quantity to meet the demands of the leather trade. Immense quantities of skins are annually imported from various parts of the world, and it may be interesting to notice, briefly, their varieties and sources.

All tanned leather is classed and known under two denominations, *hides* and *skins*. From these there are three kinds of leather tanned in England.

I. *Butts*, or *backs;* these are selected from the stoutest and heaviest ox-hides. The butt is formed by cutting off the skin of the head for glue, also the neck, the shanks, and a strip of the belly, on each side. The remaining central part, the *butt*, or *back*, of the hide, is the thickest part, and is used for purposes where great strength is required.

II. *Hides*, or *crop-hides*, consist of cow-hides, or the lighter ox-hides; they are tanned whole, and form leather which is used for ordinary purposes.

III. *Skins* are used for all the lighter kinds of leather, as will be more particularly noticed in the following enumeration.

The hides of South America are in the highest repute; they are the produce of the half-wild cattle which pasture on the wide plains between Buenos Ayres and the Andes; hides are also imported from various parts of the continent, and also from Morocco, the Cape of Good Hope, &c. In the year 1829,*

---

* In the year 1830 the duty on leather was wholly repealed.

286,416 cwt. of hides were imported, of which 166,400 came from South America, 24,000 from North America, and the remaining 66,000 from Russia, Denmark, Germany, and the Netherlands.

The *butt*, or *back*, of the ox-hide forms the stoutest and heaviest leather, and is used for the soles of boots and shoes, for most parts of harness and saddlery, for leather trunks and buckets, hose for fire-engines, pump valves, soldiers' belts, and gloves for cavalry. Formerly, when the use of metallic armour was on the decline, its place was taken by a very thick pliant leather made from the hide of the urus, or wild-bull, at that time plentiful in the forests of Poland, Hungary, and some parts of Russia. This animal was commonly called the *buffe*, whence originated the term buff-leather. The Russian Company, chartered by Henry VIII., was obliged to import a certain number of buffe-hides, to be manufactured for military purposes. Real buff-leather was pistol-proof, and would turn the edge of a sword. During the civil wars, in the reign of Charles I., it was in great request, but it afterwards declined. The hides of the real buffalo of Italy were also imported for the same purpose; but the modern buff-leather is made from cow-hide, and is used for little else than soldiers' belts.

Bull-hide is thicker, stronger, and coarser in its grain than that of the *cow*. The hide of the *bullock* is intermediate between the two. *Calves' skin* is thinner than cows', but thicker than most other skins employed. Leather is prepared from it for the bookbinder, by the process of tawing; but the greater part of the supply is tanned, and then curried for the upper parts of shoes and boots.

Sheep-skins are supplied, chiefly, by the home markets, but many thousands are imported from the Cape of Good Hope, and are considered superior to those of England, from which they are easily distinguished by the greater width of the skin that covers the tail. They are simply tanned, and employed for various purposes for which a thin cheap leather is required; such as for common book-binding, leathering for bellows, whip-lashes, bags, aprons, &c. They also form the cheaper kinds of wash-leather, for breeches, gloves, and under-waistcoats; as also coloured and dyed leathers, and mock morocco used for women's shoes, for covering writing tables, stools, chairs and sofas, lining carriages, &c.

Lamb-skins are also, chiefly, of home produce; but they are largely imported from the North of Italy and Sicily. They are dressed white, or coloured for gloves. In 1829, 1,497,000 lamb-skins were imported from Italy and Sicily, and 239,000 from Spain.

The skins of *goats* and *kids* form the best kinds of light leather. The great supply of the best kid-skins is from Switzerland and Tuscany, whence they are shipped chiefly at Leghorn. Goat-skins are principally obtained from the coast of Barbary and the Cape of Good Hope. They form the best dyed morocco of all colours. Kid-skins supply the finest white and coloured leather, for gloves and ladies' shoes. In 1829, 306,000 goat, and 106,000 kid-skins were imported. Of the former, 104,000 came from Barbary, 87,000 from the Cape of Good Hope, and 36,000 from France; and of the latter, 82,000 from the Italian ports, and 16,000 from Spain.

Deer-skins are, to some extent, supplied by our parks; but the principal supply is from New York and New Orleans; a few are sent from Canada, and some from India. *Antelope-skins* from the Cape of Good Hope are of good quality. In 1829, 120,000 deer-skins were sent from the United States, 1,780 from Canada, and 675 from India. They are all shamoyed, or dressed in oil, chiefly for riding-breeches.

Shamoyed leather of sheep, goat, and deer-skins, was formerly a celebrated and lucrative branch of the leather trade in this country. It was employed chiefly for the breeches, white or dyed, worn by persons who rode much on horseback. The English shamoyed leather was so excellent that it was not only worn by our own troops, but by the cavalry of Prussia, Austria, and most other German states. During the Peninsular war, however, it was discovered by the British commander that, in wet weather, the leathern garments fitted close to the skin, and, being longer in drying, chilled the men, and made them liable to rheumatic and other complaints. Woollen cloth was therefore substituted, and the example being speedily followed by Austria and Prussia, this branch of the leather trade speedily declined.

Horse-hide is used to a limited extent. It is tanned and curried for harness work for collars; and, being pared thin, is now much used for ladies' walking-shoes.

Dog-skin is thin, but tough, and makes good leather. The supply is entirely limited to this country, but has much fallen off of late years, being superseded as a material for thin dress-shoes by horse leather, and tanned rat-skins. *Seal-skin* is inferior to that of the dog, but is employed for similar purposes. In 1829, 289,500 seal-skins were imported, the greater part of which were from Canada; but a large proportion of this supply is used as fur in covering caps.

Hog-skin furnishes a thin, dense leather, employed entirely for covering the seats of saddles. The general custom of cooking pork with the skin on, greatly limits the supply, which is chiefly from Scotland and Yorkshire.

VEGETABLE SUBSTANCES USED IN TANNING.

In the bark of most trees there resides a peculiar and remarkable substance, to which the name of *tannin* has been applied, from the circumstance of its uniting with the gelatine of skins, and thus forming leather. The process by which tannin is obtained from vegetable substances need not be detailed, because the tanner never has to obtain it pure and separate from the woody fibres, &c., such process belonging to the scientific chemist. It will, however, be interesting to state the various proportions in which tannin exists in different vegetable substances, as ascertained by Sir Humphrey Davy. In every 480 parts of each of the following substances, there exists a quantity of tannin, as shown in the second column:

White inner bark of Old Oak	72 parts.
— — — Young Oak	77
— — — Spanish Chestnut	63
— — — Leicester Willow	79
Middle bark of Oak	19
— — Spanish Chestnut	14
— — Leicester Willow	16
Entire bark of Oak	29
— — Spanish Chestnut	21
— — Leicester Willow	33
— — Elm	13
— — Common Willow	11
Sicilian Sumach	78
Souchong Tea	48
Green Tea	41
Bombay Caoutchouc	261
Bengal ditto	231
Nut Galls	127

Thus it will be seen how greatly the quantity of tannin varies in different vegetable products; and that it is by no means indispensable to employ oak in preference to any other vegetable bark; but the advantages of cheapness and abundance cause it to be generally preferred to other substances in the tanning of thick leather; although in some tan-yards, where other kinds of bark can be more profitably procured, they are preferred to oak. Most tanners, however, state that oak-bark surpasses all other barks in producing durable leather. The price of rough oak bark varies from *5l.* to *7l.* per ton; but when freed from moss and the external core, the price becomes as much as 9*l.* per ton. Large quantities of oak-bark are imported from the continent, but the quality is not equal to that of the English.

Of late years the bark of the larch has been much used in tanning. Large quantities of *valonia* and *terra japonica,* or catechu, and also a bean-pod called *divi-divi,* have been imported, and recently the bramble and hop-bine have been used for the same purpose. Valonia produces a leather of great solidity and weight, and of a greyish colour, with much bloom on the surface. It is said to resist water better than leather made from oak-bark, which is of a light fawn colour. Leather made from terra japonica is of a dark fawn colour, inclining to red; it is light and spungy, and not waterproof. In the preparation of thin leathers *sumach* is largely employed.

PREPARATION OF THICK LEATHER.

We will now visit the tan-yard, and trace the process of a skin from its raw or *green* state, until it is converted into leather.

When hides are received fresh from the slaughter house, they are first washed in a stream of water; the horns are then removed and sold to the comb-makers; the ears and other projecting portions are cut off and sold to the glue-maker. Imported skins, which have been either salted or thoroughly dried for the purpose of preservation, require soaking in water for about ten or fourteen days.

The next operation is to get rid of the hair and scarf skin, for which purpose the hides are placed in oblong troughs or pits, containing lime mixed with water. In the course of several days the lime dissolves the hair sheath, and combines with the fat of the hide to form a kind of soap, which is easily washed off.

LIME PITS.—UNHAIRING HIDES.

When it is found that the hair can be removed, the *beam-man* places the skin upon a cylindrical table called the *beam*, and by means of a large two-handled knife scrapes off the hair, leaving what is called the *grain* of the skin. The hair is sold to the plasterer for mixing up with mortar.

The skin being once more washed, it is *fleshed;* that is, the beam-man passes a flesh-knife over the inner surface, for the purpose of getting rid of the cellular tissue and any remaining portions of fat or flesh.

The next process is that of *abating*, or *grainering*. The skins are put into a pit with a solution of dogs' dung; but if this is not to be had in sufficient quantity, its place is supplied by pigeons' dung, or by that of domestic poultry, or of sea birds. The excess of lime is removed by the lithic acid of the dung; and the ammonia formed by the putrefaction of the mixture, forms a soap with any remaining fat of the hide. The skin also becomes thinner by a portion of the gelatine being dissolved, and if left too long in the mixture it would be reduced to a tender jelly-like mass: hence considerable care and judgment are required in regulating this part of the process.

The skins are now again worked on the beam, in order to get rid of all slime, dirt, &c., and are afterwards immersed for twelve hours in a very weak solution of sulphuric acid, called *sours*, for the purpose of *raising* or thickening the skin; the only use of this process, according to some, is to make the leather look thick when completed; but it probably assists the entrance of the tan into the pores of the skin, and may thus produce better leather, and shorten the process of tanning.

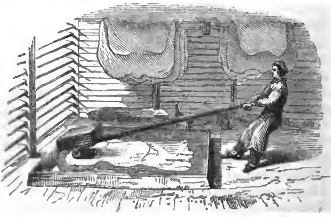
All these preparatory processes being completed, the actual tanning now commences. The tan-yard generally occupies a large extent of ground, and above it are lofts for drying the leather when it is tanned. The tan-pits* are formed in the earth, and lined with deal planks; they are oblong in shape, and from six to eight feet in depth. They are ranged in rows side by side, a space being left between them for the convenience of the workmen. The oak-bark is ground by a mill, attached to the yard, and the solution of bark, called *ooze*, is prepared in pits expressly reserved for the purpose. From these pits it is drained off into an ooze-well, whence it is pumped into shoots, and conveyed to any part of the yard. Since ooze of various degrees of strength is required, it is sometimes usual to employ a kind of hydrometer, called a *barkometer*, for measuring it. The instrument is graduated by the standard of pure water, and the ooze is said to be strong or weak, according as it rises above or sinks below the water-mark. But these indications are not always to be depended on, since the ooze dissolves a portion of the gelatine of the skin, and would hence appear to be strong when the tannin had been almost entirely exhausted. The more usual test of ooze is a solution of pure gelatine, such as isinglass, which unites with the tannin, and forms a precipitate, more or less dense, according as the ooze is strong or weak. The strength of the ooze is also judged of with tolerable accuracy by its taste, which in strong oozes is highly astringent.

---

* See Frontispiece.

A number of hides being prepared by the processes already described, they are placed one by one, as open as possible, in pits containing nearly spent ooze. These pits are called *handlers*, because the skins are frequently taken out, and *handled* in the early stages of the process. The tannin begins to combine with the gelatine of the skin immediately the two are brought into contact, and hence a weak ooze is spent in a few hours; the skins are therefore removed to a pit containing a stronger ooze, and thus, for the first few weeks, they are shifted daily to oozes gradually increasing in strength. They are removed from the pits by two men, furnished with hooks; and are piled up at the side to allow the spent ooze to drain from them. Each pit contains several dozen hides, and one of the objects of this repeated *handling*, is to ensure the equal action of the tannin upon all the hides. In the course of a few months they are removed to other pits, called *layers*, where the ooze is nearly saturated, and the strength is maintained by a quantity of ground bark (sometimes of valonia) between every two hides. They remain in the layers undisturbed during some weeks.

The time required for tanning hides varies from nine to fifteen months; and for skins from three to five months. In the course of tanning, the whole of the skin or dermis disappears by successive formations of the compound of gelatine and tannin, on both sides of the hide, until all traces of the animal substance disappear. In an early stage a thick whitish line is seen on cutting across a hide: this is a portion of the skin itself; but as the process proceeds this also disappears, and the tanner knows that the process is complete. The skins are then hung up in lofts to dry, and, once or twice during the drying, they are placed upon a cylindrical bench, and *struck* or smoothed with a square bar, the surface being occasionally wetted: the effect of this operation is to produce on the surface a yellow deposit called *bloom*, or *pitching*. This appearance is so much preferred by shoemakers, that if it were absent they would, probably, refuse to purchase the leather; it is, however, of no advantage, but rather the reverse, being in fact caused by a portion of the interior of the hide dissolved by the saturated ooze, to remove which from the interior to the exterior must prove injurious to the solidity of the leather. When the drying is sufficiently advanced, the hides are submitted to the action of a brass roller, about nine inches wide, loaded with from fifteen to thirty cwt. This is called *finishing*, and when complete, the hides are fit for the market.



"FINISHING" HIDES.

It will be seen from these details that tanning is a very slow process. Many plans have been adopted for hastening it: such as forcing the ooze into the hide by hydrostatic or atmospheric pressure; but these have failed, the leather so produced being pronounced to be of inferior quality; parts of the hide which are hard not having time to become perfectly saturated with the tanning liquor, an irregularity in the quality of the leather is the result. The very obvious method of increasing the strength of the ooze more rapidly than is customary, shortens the process, but the leather is hard and liable to crack. The same objection applies to warm oozes. The plan of employing strong oozes, from the commencement, fails, because solutions containing an excess of tannin dissolve the skin. Hence the old method continues to be practised, and to receive the sanction of eminent tanners and of scientific men. Sir Humphrey Davy states that leather slowly tanned in weak ooze, appears to be better in quality, being both softer and stronger, than when the process is hurried by employing strong ooze from the first.

There is, however, a new process for tanning, which has recently excited considerable attention. It is by Mr. Herepath of Bristol, who has patented the invention. That gentleman is of opinion that the great obstruction to rapid tanning is this:—the skins retain so much of the weakened ooze, that when placed in a stronger ooze, the latter cannot enter the pores already saturated with water or very weak ooze, except after weeks or months of maceration, during which time the exchange is being slowly made. In passing the skins from a weak to a stronger ooze they are therefore pressed between rollers, a pair of which is erected over each pit. The lower roller is about thirty inches in diameter, and is covered with horse-hair cloth; and the upper roller, which is loaded, is only about eighteen inches in diameter, and is covered with woollen cloth. For each pit fifty hides are formed into an endless band, by sewing them together with twine. Upon introducing this band between the rollers, the hides are successively lifted from the bottom of the pit, strongly pressed by rollers, and then returned into the pit for a fresh supply of ooze. Mr. Herepath states, that each ooze becomes exhausted about two degrees of the barkometer in twenty-four hours, when it is pumped to the next pit of the series. It is said that by this process a strong hide may be completely tanned in six or eight weeks, and calf-skins and *kips* (the hides of young cattle) in from twenty to thirty days. The thickest hides, or *butts*, can by this process be prepared within four months of their being received in the tanner's yard; and the increase in the weight of butt leather, as compared with that made in the usual way, is stated to be as 34lbs. to 28lbs.

The opinions formed of the merits of this process are so contradictory, that the writer cannot venture to quote from them. The efficacy of the method must be tried by the quality of the leather; if it be superior or even equal to that produced by the old process, the new plan must be regarded as a national benefit; but if the leather be hard and brittle, the plan will, sooner or later, be abandoned.

It is generally the object of the tanner to make every hide or skin as heavy as possible, since he sells it by weight. The fair average weight of a good skin of uncurried leather is half the weight of the green hide, and the tanning is not considered successful if the weight be less.

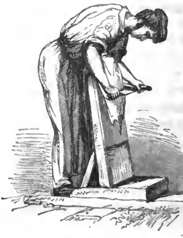
Before taking leave of the tan-yard, the writer must refer to the heaps of spent bark which form a prominent feature therein. This refuse matter is applied to various uses. It is formed into cakes by pressure in iron moulds, and sold in London under the name of *turf*, as a cheap fuel. It also supplies the place of the more expensive article straw, thrown down in the streets of London opposite the house of a sick person, for the purpose of deadening the noise of carts and carriages. A third use is for the purpose of forming hot-beds; when collected in a heap, it slowly putrefies, and forms a fine vegetable mould. Most of the pineapples of this country are grown in a compost, into which the spent bark largely enters. After it has served its purpose in the hot-bed, it is transferred to the farmer, who finds it a useful manure.

CURRYING.

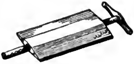
We will now transfer our skin of leather from the tan-yard to the currier's premises; where, by a series of mechanical operations, it will be transformed into a smooth, shining, and pliable skin, adapted to the purposes of the shoemaker, the coachmaker, the harnessmaker, &c. We will first trace the operations of the currier upon a tanned calf-skin.

The skin is first thoroughly soaked in water, in order to make it pliable; then taken to the beam, and shaved on the rough flesh side, whereby its thickness is considerably reduced, and the unequal surface brought to a tolerably smooth and even one. This is one of the most curious and laborious operations of currying.

The beam shown in the accompanying figure consists of a strong frame of wood, supporting a stout plank faced with lignum vitæ, and made very smooth; this plank can be set at a greater or less inclination, and sometimes it is permanently fixed in an upright position. The knife, which is double-edged, is a stout rectangular blade, about twelve inches long by five wide; at one end is a straight handle, and at the other a cross handle, in the direction of the plane of the blade. The edge of the knife is brought up by means of a whetstone, and a wire edge is afterwards produced, and constantly preserved by means of a small steel tool, which the beam-man always has between his fingers while using the knife. The skin being thrown upon the plank, as in the figure, the man presses his body against the skin, to prevent it from slipping; and holding the knife by its two handles, and nearly perpendicular to the leather, he



THE BEAM-MAN.



shaves off from the thick parts, and, after every shaving, passes a fold between his fingers, and thus ascertains the state of the skin with respect to evenness. When sufficiently reduced by shaving, the skin is again thrown into cold water, scoured, and extended. For this purpose it is placed upon a large stone table, to which the flesh side of the wet skin adheres, and is worked with a tool called the stretching-iron; this is a flat rectangular piece of iron, copper, or smooth hard stone, fixed in a handle, with the corners rounded off to prevent injury to the leather; the workman holds this tool with both hands, and, using plenty of water, scrapes the surface with a very strong pressure, especially at those parts where lumps and inequalities appear. By the continued action of this tool the leather is extended or stretched, while at the same time the *bloom* is brought to the surface.

When the skin is thoroughly cleansed, and while yet in its wet and distended state, the process of *stuffing*, or *dubbing* (probably a corruption of *daubing*), is performed. Both sides of the skin, but chiefly the flesh side, are smeared or daubed with a mixture of cod-oil and tallow, which is then well rubbed in by means of a brush, or a piece of old sheep-skin with the wool on. The skin is then hung up in a loft to dry; but as the water only evaporates, the greasy substances sink deep into the pores of the leather. In very moist weather the skins are stove-dried, the fuel for the stove consisting of leather shavings, and thus a most nauseous odour is diffused over the neighbourhood of the currier.

When the skin is sufficiently dry, it is *boarded*, that is, worked with an instrument called the *pommel*. The object of this is to bring up the *grain*, that is, to give the leather a *granular* appearance, and also to make it supple. The pommel is a piece of very hard wood, furnished with a strap on the upper side, for the insertion of the hand,* and grooved (like a crimping board) on the under side, which is convex. The leather is folded with the grain side in contact, and rubbed strongly on the flesh side with the pommel; this part of the process is called *graining*. It is then extended and rubbed on the grain side; this is called *bruising*. The skin is next taken to the beam and *whitened*, that is, the knife is passed lightly over it, whereby the flesh side is thoroughly cleaned and brought to a fit state for *waxing*,—a process which is never performed until the skin is required for immediate sale; for at this part of our history, the currier stores his skins, because they are brought to that state (technically called "finished russet") in which they can be best preserved for any length of time. Previous to waxing, the skin is boarded a second time. The first part of the process of waxing consists in laying on the "colour," or blacking, which is composed of oil, lamp-black, and tallow; the colour is rubbed in thoroughly on the flesh side, by means of a hard brush: it is then *black-sized;* that is, a coat of stiff size and tallow is laid on with a soft brush or a sponge, and well rubbed with a smooth lump of glass called a "slicker;" and lastly it receives its final gloss from a little thin size laid on with a sponge. The skin of leather now curried is called "black on the flesh," or "waxed," in contradistinction to leather which is curried on the hair or grain side, called "black on the grain;" and which is chiefly used for the upper leathers of ladies' shoes; the former, or "waxed" leather, being employed for the upper leathers of men's boots and shoes.

---

* Hence the origin of the word pommel, from the French *paumelle*, because it clothes the *palm* of the hand.

The processes for currying leather on the grain side are similar to those already described, until we come to the process of scouring. *Copperas water,* that is, sulphate of iron dissolved in clean water, or in the water from the tank in which the skins have been soaked, is applied to the grain side of the skin while wet. The iron unites with the gallic acid of the tan, and thus produces an ink dye; the skin is then rubbed over with a brush dipped in stale urine, and when this is dry the stuffing is applied; it is rubbed over with copperas water on the grain side until it is perfectly black. The grain is then raised, and when quite dry, the skin is whitened, bruised again, and grained in two or three ways; a mixture of oil and tallow is then applied to the grain side, and the currying process is complete.

Digitized by Google

PREPARATION OF THIN LEATHER.

In addition to the tan-yard, properly so called, where the thickest and largest skins of leather are made, there are other establishments which contribute extensively to the immense demand for thin leathers; such as *white* and *dyed* leather for gloves, *morocco* of various colours and qualities for coach-lining, book-binding, pocket-books, &c., being an imitation of that prepared in Morocco, and other parts of North Africa; *roan* for slippers, &c.; a thin leather called *skiver*, used for hat-linings, and an infinite number of other purposes; and, lastly, *shamoy*, or *wash*-leather.

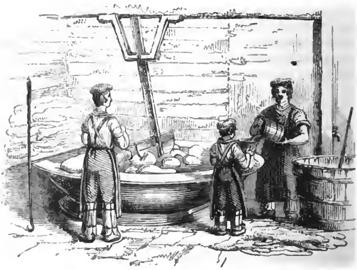
Of all these varieties, white leather alone is not tanned, but tawed. The difference between the two processes is, that the gelatine of the skin is combined with tannin in the one case; and in the other with something which it imbibes from alum and salt, probably alumine. But, for either process, certain preparations are necessary, whereby hair, wool, grease, &c., are removed, and the skin, thoroughly cleansed, is reduced to the state of simple membrane, called *pelt*.

The preparatory steps vary, according as the skin is covered with wool, or short hair; the one being a valuable commodity, and the other comparatively worthless, its chief use being by the bricklayer to mix with mortar. The hair of kid and goat skins, &c., is therefore detached by immersing the skins in lime, as already described; but as this plan would injure the wool, a different method is adopted. The wool is usually detached from *sheep*-skins before they arrive at the tawers. This is done by the great dealers in sheep-skins, who are called *fell-mongers;* they receive the skins from certain factors, or salesmen, in the skin-market, by whom they are procured from the butchers. The lamb-skins of Italy are imported in casks with the wool on, so that the tawer adopts a process for removing it similar to that employed by the fell-monger. They are first cleansed in water, and then scraped on the flesh side. They are then hung up in considerable numbers, in a close, dark, warm room, where they are *sweated*,—that is, putrefactive fermentation soon commences, a thick filthy slime appears on the surface, and the effect of this is so to loosen the wool that it can be pulled off easily. Much care and judgment are required in regulating the fermentation of the skins, so that their texture be not destroyed. When the wool is removed, the fatty matters are got rid of by the powerful force of a hydraulic press; a large number of skins being piled up, a considerable quantity of fat is expressed; this is afterwards sold to the tallow-chandler. The skins are then worked at the beam; projecting flaps and rough edges are pared off for the glue-maker, and putrefaction is arrested by immersion in lime, for a space varying from two to six weeks. They are first put into a nearly exhausted lime-pit, and afterwards into a stronger one, and are frequently worked about with poles. When taken out they are well worked at the beam, the object being to get rid of a portion of the lime; and this is more completely effected by immersion in a fermenting mixture of dogs' or pigeons' dung, if the skins are to be tanned, and of bran and water, if they are to be tawed, the acid of which unites with the lime, and further purifies and softens the skins. During the time that the skins remain in this mixture, they are occasionally taken out and worked at the beam, and are lastly washed in pure water. By such means the pelt becomes a thin extensible white membrane, and is fit for *tanning, tawing, dying, oil-dressing*, or *shamoying*. A brief notice of each of these operations will serve to convey some idea of the extent and importance of the manufacture of thin leathers.

TANNING WITH SUMACH.

The substance used in tanning goat, and other thin skins, is sumach, or the leaves, leaf-stalks, and young branches of the *Rhus coriaria,* and *Rhus cotinus,* shrubs which grow in Hungary, the Bannat, and the Illyrian provinces. They contain much tannin, and a small quantity of a delicate yellow colouring matter. It is said that all the leather made in Turkey is tanned with the bark of the *Rhus coriaria.*

When goat-skins are tanned with sumach, and then dyed on the grain side, they form what is called *morocco* leather; but an inferior morocco is prepared from sheep-skin. When the skins are in the state of perfectly clean white pelt, each skin is sewn by its edges, into the form of a bag, the grain side out; it is then distended with air, and a mordant of tin, or alum is applied. The object of forming the skins into bags is two-fold; first, to economise the dye stuffs, (some of which are costly,) by dying the skins on one side only; and, secondly, to ensure a perfectly equable action of the dye, and also of the solution of sumach. If the colour is to be red, the skins are immersed in a warm cochineal bath; indigo is used for blue; orchil for purple, &c.: and they are worked by hand until uniformly dyed. For other colours the pelt is tanned before dying. The sumaching is conducted in a large tub, containing a weak and warm solution of sumach. A stronger solution is made in another vessel, and a portion of this, together with some sumach leaves, is poured into the bag, by means of a funnel, through an opening left for the purpose. This is diluted with a quantity of the nearly spent solution in the vat; each skin, after having received its share of the tanning liquid, is handed to a man who blows into it, and fully distends it; he then ties up the opening, and throws the skin into the vat. About fifty skins are treated in this manner; they all float in the sumach-tub, and



THE SUMACH-TUB.

are moved about by manual labour, or by machinery, during three hours. They are then taken out, and piled on a sloping shelf by the side of the vat, the mutual pressure thus produced causing the sumach to escape slowly through the pores of the pelt. The bags are being constantly shifted by a man, who watches whether the solution escapes from the seams: if so, he secures them by a few stitches. They are next transferred to a second vat, containing a stronger solution than the first; and here they remain about nine hours, at the end of which time the tanning is complete. The skins are ripped open, rinsed, and drained. The colour of the fine red skins is finished in a weak bath of saffron; and, lastly, all the skins, of whatever colour, are stretched upon a smooth sloping board, and *struck*,—that is, scraped and rubbed out, until they become smooth and flat. Sometimes they are sponged on the grain side with linseed oil, in order to promote their glossiness in the subsequent process of currying.

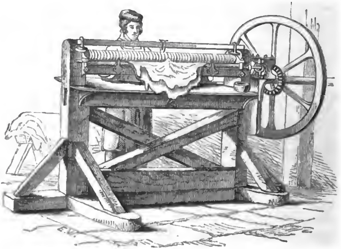
The skins are then removed to a loft, and dried.

In drying they assume a horny texture, and are said to be *in the crust.* After this comes the process of currying, or finishing. The skins are again placed upon the smooth sloping board, and rubbed several times with the pommel, and also with a glass ball, cut with smooth sides upon its surface; this polishes them, and makes them firm and compact.

"FINISHING" THIN LEATHERS.

The grained, or ribbed appearance, peculiar to morocco leather, is imparted by a ball of box-wood, round the circumference of which are cut a number of narrow ridges. This is passed many times over the skin with a firm pressure, and its effect is not only to improve the surface of the skin, but also to add to its pliability and softness.

The preparation of an imitation morocco from sheep-skins, does not differ essentially from the processes just described; but there is one remarkable process applied to sheep-skins, which must be noticed. When they are in the state of pelt, they are *split;* that is, every skin is divided into two skins of the same size, but, of course, of only half the thickness of the pelt. This is effected by means of a very beautiful machine called the "skin-splitting machine." It consists of two rollers, the lower one of solid gun-metal, and the upper one composed of rings of the same material; these cylinders are made to move slowly in opposite directions; and between them, but not in contact, is a knife, with a sharp cutting edge, to which a rapid reciprocating motion is imparted. In order to *split* a skin, a man stands on the side of the machine, opposite to the knife edge, and, upon the lower or solid roller, spreads evenly the end of a skin or pelt; it is caught up by the rollers, and dragged forward against the edge of the knife, by which it is divided; one half going above, and the other below the plane of the blade. During the whole of the operation the man continues to adjust the skin upon the lower roller, the smooth solid surface of which gives support and stability to the skin, while the upper roller, being composed of movable rings, adjusts itself to any unevenness of the membrane. In parts where it is thin, the rings are depressed; where it is thick, they are elevated; hence no part escapes the action of the knife, and no



SKIN-SPLITTING MACHINE.

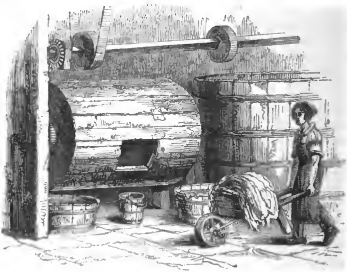
holes are produced in either half. The men are furnished with gloves, to prevent their fingers being caught up by the rollers. About two minutes are occupied in splitting a sheep-skin, during which time the knife is moved to and fro nearly three thousand times. When three or four of these machines are at work in one room, the noise is deafening.

In order to show the precision with which this beautiful machine works, sheep-skins have been split into *three* parts of equal size; the grain side being used for skiver, &c.; the middle for making parchment; while the flesh side was transferred to the glue-maker. The divided skins, or skivers, are sumached in a short time, their thinness rendering the sewing up into bags unnecessary.

TAWING.

The preservation of an animal skin, by means of alum and salt, is called *tawing;* and the object is to employ such materials as will not interfere with the production of a pure white leather. In all the finer kinds of leather-dressing, the perfect purity of the pelt is of the utmost importance, for without it the subsequent operations would be thrown away; every particle of dirt, or lime, which is allowed to remain, appearing as a speck or a flaw. The purity of the water used for rinsing the skins is also a point of great importance. At Messrs. Bevington's manufactory (which the writer was permitted to inspect) a sufficient supply of distilled water is obtained from the boiler to the steam-engine, which is made larger than usual for this express purpose.

Kid-skins, for the best kid-leather, and sheep, or lamb-skins, for an inferior sort, being reduced to the state of pelt, the first process in tawing, is to "give them a feeding" with alum and salt. About three pounds of alum, and four of salt, are used to one hundred and twenty middle-sized skins. The solution, together with the skins, is put into a drum, or tumbler, to which a rapid motion is imparted. The action of the alum and salt upon the skins is not well known, but it is supposed that alumine and gelatine form some definite compound, and that the salt serves to whiten the skins. After some time they are taken out, washed in water, and then put into bran and water, where they are allowed to ferment, till the superfluous alum and salt are removed, and the thickness produced by them is reduced. They are next transferred to the drying loft, stretched on hooks, and allowed to remain till fully dry. They now form a white, tough, brittle leather; but the glossy finish and softness of kid is imparted by a dressing composed of twenty pounds of the finest wheat flour, and the yolks of eight dozen eggs.* This paste,

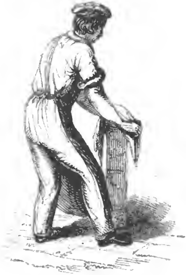


TAWING DRUM.

---

* This egg-dressing is indispensable in the preparation of white lamb and kid-leather. The eggs used for the purpose are imported from France and Flanders; and at the time of the writer's visit to Messrs. Bevington's factory, they had a stock of 60,000 eggs pickled in salt, which preserves them admirably.

diluted with water, is put into a drum, and the skins are made to rotate therein, when they so completely imbibe the egg-liquor, that scarcely anything more than water remains. This dressing is generally repeated before the skins are hung up to dry. But the softness and elasticity yet remain to be given. The skins are dipped into pure water, and allowed to remain for a few minutes; they are then spread out, and worked upon a board, and *staked* upon the *stretching* or *softening* iron. This is an iron plate, rounded over at the edge, mounted upon an upright beam, and fixed to a heavy plank, well secured in the floor. By these processes the skins are considerably extended in length, and all hard points and roughnesses removed. They are finally smoothed with a hot iron, and are then ready for the glover.



"STAKING" TAWED LEATHER.

DRESSING IN OIL

Consists in first soaking the skin in water, and then, by continued hard rubbing, forcing oil or grease into its pores. As the water evaporates, the oily matter combines in some way with the fibres of the skin; renders it permanently soft, and, by keeping out the water, prevents it from decay.

A process of this kind was formerly applied to the skin of the Chamois goat, and hence arose the term *chamois*, *shammy*, or *shamoyed*, as applied to the leather itself, and *shamoying* to the process. As this is the only kind of leather which, when dyed, will bear washing without the colour being materially injured, it is also called *wash*-leather.

Wash-leather is prepared, in this country, from doe's or sheep's skin: and for the inferior kinds, the flesh side of sheep's skin, as obtained from the split hide, is employed; the other half, or grain side, being tawed for skiver-leather. Indeed, it is common always to get rid of the *grain* before a skin is shamoyed; because, by doing so, the extensibility and softness of the skin are much increased. The grain is removed by an operation called *frizing;* that is, one end of the skin is wrapped over a pole, the grain side uppermost, and then the whole surface is scraped with a round knife, or with pumice-stone.

The grain being removed, the skins are placed in some bran liquor, and then wrung out; they are afterwards spread upon a table, sprinkled slightly with oil, and folded up in balls of four each, and beaten by a number of heavy wooden hammers in the *fulling stocks*. The heads of the hammers are covered with copper, and they work in a kind of trough, in which the skins are placed. After having been beaten for two or three hours, according to their texture and the state of the weather, they are taken out, exposed to the air, oiled and fulled several times, until all appearance of greasiness has disappeared. They are next hung up in a warm room, when a kind of fermentation takes place, which opens the pores of the skin, and promotes the combination of the oil. They are then scraped with a blunt concave knife, and scoured in a weak warm potash lye, in order to get rid of the uncombined oil. Having been washed in water, they are gently dried, smoothed, and made supple by the stretcher iron, or by passing them between rollers.

STATISTICS OF LEATHER.

In the year 1830, the duty on leather was wholly repealed; so that there are now no means of ascertaining the quantity produced in any one year. The yearly production, on an average of three years, ending in 1822, was 48,244,026 pounds. In this year the duty was diminished from 3*d.* to 1½*d.* per pound; and the average production of the next three years showed an increase of 30 per cent. The repeal of the duty and the increase in population have, doubtless, increased the consumption of leather to an equal, if not greater, extent. It has been calculated that the annual production, at this time, is about 82,000,000 pounds; the value of which, taking one quality with another, at 1*s.* 4*d.* per pound, amounts to 5,466,000*l.* It is supposed that the value of the leather forms only one-third of the finished articles, so that the ultimate value of the manufacture, in Great Britain alone, must be 16,400,000*l.* Some estimates are even higher than this, and make the aggregate value of leather goods to exceed 21,000,000*l.* per annum. "Nor will this amount appear excessive," says Mr. M'Culloch, "if we consider that there is only a very small proportion of the people, however poor they may be, who do not wear leather shoes or boots; that the use of leather gloves is general among all but the labouring classes; and that the harness of horses used for pleasure, as well as those used for agricultural and other business operations, is made with this material, besides an endless variety of things in daily use, which will suggest themselves to every one's mind."

Some idea of the importance of the leather manufacture may be formed by considering the value of the shoes annually manufactured. It is generally supposed that the expenditure upon shoes may be taken, at an average of the whole population, at 10*s.* per annum for each individual, young and old, which, supposing the population to amount to nineteen millions, would give 9,500,000*l.* for the value of shoes only; but taking the value of shoes at only 8*s.* 6*d.* each individual, it gives 8,075,000*l.* for the amount. It has been supposed that the value of saddlery, harness, gloves, &c., is, at least, equal to that of shoes, but this estimate is thought to be too high.

The leather manufacture does not seem to exert any injurious action on the health of those engaged in it. Tanners are exposed to disagreeable odours, arising from putrefying skins combined with the smell of lime, or of putrid substances used in dressing them. The smell of the tan-pits is penetrating, but not by any means unwholesome; the men do not seem to suffer from any of these causes; and, although constantly exposed to wet and cold, they are robust, and disease is almost unknown among them.

In consequence of the odours diffused by tan-yards, they are generally situated at the outskirts of a town. During a long period, Bermondsey was the principal seat of the leather manufacture in England, on account of the Thames tide-streams affording an abundant supply of water. Although the Bermondsey manufactures are more extensive than ever, tan-yards are established near most of the towns of this country.

Curriers and leather-dressers sometimes suffer from the bent posture required by their work: this affects the head; but otherwise they are exposed to no injurious agent.

THE

MANUFACTURE OF PARCHMENT.

The preparation of parchment from the skins of animals is closely connected with the manufacture of leather, and therefore requires to be noticed in this place.

Parchment derives its name from *Pergamus*, an ancient city of Mysia, where it is said to have been invented by Eumenes II., king of that place, (who reigned B.C. 197—159,) in consequence of the prohibition, by Ptolemy Epiphanes, to export papyrus from Egypt. It is, however, nearly certain that the invention must be referred to an earlier date, and that Eumenes was only an improver, or the patron of some improvements, in the manufacture at Pergamus.

As soon as men had invented written characters, they would naturally seek after the means of preserving some record of their most important transactions. Memorials of stone and of metal were long used for solemn occasions, while tables of wood were in more familiar use; leaves of trees and the inner bark were convenient substitutes for leather; but, perhaps, the most useful material was animal skin or membrane, which seems to have been used at a very remote period.

Some kind of animal membrane, or parchment, seems to be indicated in the "great roll" which the Lord commanded the prophet Isaiah to write "with a man's pen," (Isa. viii. 1,) and also the "roll of a book" in which Jeremiah wrote the words of the Lord, and which was cut with a penknife and cast into the fire, piece by piece, by Jehoiakim, king of Judah, as it was read in his presence, (Jer. xxxvi. 2, 22, 23,) and a book described by Ezekiel as being written within and without with "mourning, lamentations, and woe." (Ezek. ii. 9.)

The ancient Persians are said to have written their records upon skins, and it is known that the Ionians employed the skins of sheep and goats for writing on, at a very remote period, understood to be many centuries before the time of Eumenes. The antiquity of parchment as a material on which the Holy Scriptures were transcribed, is shown also by an interesting discovery of the late Dr. Buchanan, who found in the record-chest of the Black Jews at Malabar, an Indian copy of the Pentateuch, written on a roll of goats' skins, dyed red. This ancient and beautiful manuscript was discovered in 1806, and is now deposited in the public library at Cambridge. The roll measures forty-eight feet in length by twenty-two inches in breadth. The book of Leviticus, and the greater part of the book of Deuteronomy, are wanting; and it appears, from calculation, that the original roll measured not less than ninety feet. In its present condition it consists of thirty-seven skins, with one hundred and seventeen columns of perfectly clear and legible writing.

Although the word *roll* occurs several times in the Holy Scriptures, the word *parchment* is not mentioned more than once. (See 2 Tim. iv. 13.) The word in the original Greek, however, is *membrane;* and it is stated that the name *Pergamena* was not used until several centuries after the death of Eumenes.

We are not clearly informed of the ancient method of preparing parchment. In the seventh century it seems nearly to have superseded the use of papyrus, and also to have been used for strengthening and supporting written leaves of that fragile material. About the eleventh century the manufacture degenerated, from the circumstance, it is supposed, of writers preparing their own parchment. This practice is recommended by Hildebert, archbishop of Tours, (born in 1054,) who, in a sermon on the "Book of Life," which he recommends his hearers to obtain, says—"Do you know what a writer does? He first cleanses his parchment from the grease, and takes off the principal part of the dirt; then he entirely rubs off the hair and fibres with pumice-stone: if he did not do so, the letters written upon it would not be good, nor would they last long. He then rules lines, that the writing may be straight. All these things you ought to do, if you wish to possess the book which I have been displaying to you." About this period parchment was a very costly material, and hence arose the practice of paring or washing off the contents of an older manuscript for the sake of the material. Thus, many a beautiful poem or valuable history has been sacrificed to make way for a monkish legend; but ingenious and learned men having discovered means for deciphering the original writing, many valuable old classic productions have thus been preserved to the world. An old French writer, speaking on this subject, says:—"Some parchment has been restored three or four times, and has successively received the verses of Virgil, the controversies of the Arians, the decrees against the books of Aristotle, and, finally, the books of Aristotle themselves. Parchment is like an easy man, who is always of the same opinion as the last speaker." The practice of using parchment many times over was so common in the fourteenth and fifteenth centuries, that the diploma of the Imperial Notary of Germany expressly prohibited the use of *scraped* vellum in drawing deeds.

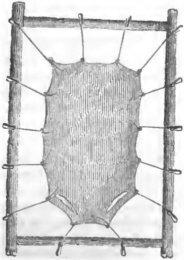
The invention of paper, in great measure, superseded the more costly vellum or parchment, although this substance was frequently used in printing. Dr. Dibdin states that almost all the known works before 1462 are printed upon vellum; the Psalters of 1457 and 1459 are upon vellum; and that of the Bible of 1462, more copies have been described upon vellum than upon paper.

PREPARATION OF THE SKINS.

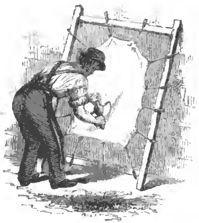
DR. DIBDIN, in his *Bibliographical Decameron*, quotes a little book of Arts and Trades, which appeared at Frankfort in 1568, 12mo, with cuts, in which the parchment-maker is seen at work with tools and apparatus closely resembling those now in use; so that the processes about to be described have, probably, been followed during many centuries.

The skin of almost every animal is capable of being made into parchment; but that of the sheep or the she-goat is usually preferred. The finest kind of parchment, called *vellum*, is made from the skins of calves, kids, and dead-born lambs; the stout parchment, used for drum-heads, is made from the skins of asses, calves, or wolves, preference being given to the latter; the parchment of battledores is from asses' skin; and for sieves, the skin of the he-goat is preferred.

These skins are all prepared in the same way, or nearly so. Wool, hair, and fatty matters are got rid of by some of the processes which have been already described, and, when thoroughly cleansed, the skins are stretched in such a way as to prevent puckering, and to admit of their being easily worked. For this purpose a stout wooden frame, called a *herse*, is employed. It consists of four bars, perforated with a number of holes, in each of which is a wooden peg, which works in the same manner as the peg of a violin or a guitar. In order properly to stretch the skin, a number of pieces of twine are tied firmly to its edges, and,

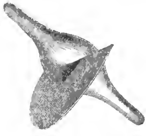

THE HERSE.

to prevent them from slipping when the skin is strained tightly, each string is tied round a small wad or ball, formed by rolling up a shred of skin, and wrapping this into a small fold at the side of the skin which is to be strained. Sometimes skewers of several sizes are used: these are stuck into the edges of the skin, and the string is then firmly secured to them. The other extremity of each string is next passed through a hole in the side of the peg, and in turning this the string is wound round it, and thus the skin is gradually and equally strained. The pegs are first turned by hand, and afterwards with a key. The greatest possible care is required to prevent the formation of wrinkles.



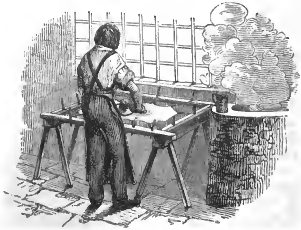
SCRAPING.

The skin being properly strained, the herse is set up against the wall, and the skinner proceeds to scrape the surface with a semicircular double-edged knife, attached to a double wooden handle. This is sometimes called a *half-moon knife*. The skinner uses this knife with both hands, and pressing the edge against the skin, shaves off all fleshy substances. He next turns the herse so as to expose the grain side of the skin, and passes the knife over every portion of it. By this means dirt, slime, and a considerable quantity of water, are removed.



HALF-MOON KNIFE.

The next process is *grinding*. The skin is placed upon trestles, and sprinkled on the flesh side with finely powdered chalk or slaked lime, and then rubbed in all directions with a flat surface of pumice-stone. The grain side of the skin is next ground, but without the addition of chalk or lime. The knife is again passed over the skin, and the scouring with chalk and pumice-stone is repeated. This scraping with the knife is called *draining*, and serves to whiten the skin. The skinner then rubs fine chalk over both sides of the skin with a piece of lamb-skin that has the wool on: this makes the skin smoother, and gives it a white down or nap, but great care must be taken not to scratch the surface. The skin is then removed to a covered shed to dry. In warm weather a moist cloth is occasionally applied to it, and the pegs are tightened. When perfectly dry, it is well rubbed with the woolly side of a lamb-skin, in order to get rid of the chalk. If any greasy matter should now be detected in the parchment, the skin is removed from the herse, and again steeped in the lime-pit for several days; but if the result is satisfactory, the



GRINDING AND DRAINING.

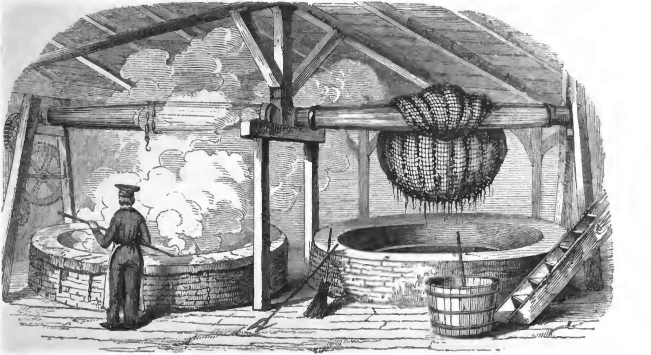
skin is removed from the frame by cutting it all round.

The skin is then passed to the *parchment-maker*, who stretches it upon a machine called the *sumner*, which is nothing more than a calf-skin mounted upon a frame. The tail of the skin being placed downwards, the parchment-maker then takes a sharp circular knife, and passes it over the outer surface, in an oblique downward direction, paring off about half of its thickness, and leaving it perfectly smooth; this is an operation requiring great flexibility of the wrist and considerable skill. The skin is scraped on the grain side only, and any remaining roughness is removed by rubbing with pumice-stone upon a kind of form or bench, covered with parchment, and stuffed with flock; this process leaves the parchment fit for writing on. If any small holes appear in the skin they are stopped by cutting the edges thin, and pasting on small pieces of parchment with gum-water.

Parchment is coloured green for binding. The following is a common method of imparting the colour:—In 500 parts of distilled water are boiled eight of cream of tartar, and thirty of crystallized verdigris; when the solution is cold, four parts of nitric acid are added. The parchment is first moistened with a brush, and the colour then spread evenly over the surface. Polish is given by white of egg or mucilage of gum arabic.

Digitized by Google

Digitized by Google



GLUE BOILING.

THE

MANUFACTURE OF GLUE.

◆

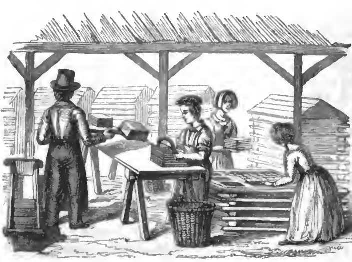
GLUE is a preparation of gelatine in a dry state, and is made from the refuse of the leather-dresser and the parchment-maker. All the projecting flaps, the roundings, scrapings, and cuttings of skins, anything, in short, that contains gelatine, may be employed in the manufacture of glue. The following account of the process is chiefly derived from a visit to the works of Mr. Alfred Bevington, of Bermondsey, who has kindly permitted sketches of his machinery to be taken.

On receiving the refuse material from the leather-dresser, the first process is to make it clean and to get rid of matters which do not afford glue; the pieces are, therefore, immersed in a lime-pit, and when sufficiently steeped they are placed in baskets, and rinsed in a stream of water, and then placed on hurdles to dry. Whatever lime remains is converted into chalk by exposure to the air; and although lime would be injurious to the after processes, yet the presence of a minute portion of chalk is immaterial.

The gelatine is extracted from the pieces by boiling. For this purpose they are placed in a rope cloth, which is spread open within a large iron cauldron; a light framing of iron is contained within the cauldron; to prevent the cloth from sticking to its sides. Water is then added, which is gradually brought to the boiling point; as the animal substances sink, fresh quantities are added, the whole being

Digitized by Google

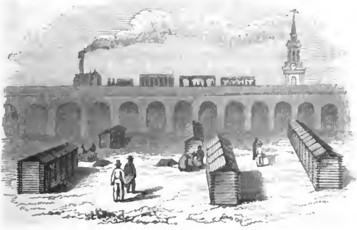
occasionally stirred up and pressed down with poles. As the boiling proceeds, portions of the gelatine are taken out and set aside to cool, and when, on cooling, a clear mass of jelly is produced, the boiling is judged to be complete. The ends of the bag are brought together by means of cords, and by giving motion to the machinery over the cauldron, the bag is slowly lifted out of it; the gelatine drains off, and this is further assisted by causing a portion of the bag to coil round the beam as shown in the frontispiece. The solution of gelatine in the cauldron can, if necessary, be further evaporated by continuing to apply heat. The contents of the bag are boiled a second and a third time for making size, and when the solutions are too weak to produce either glue or size, they can be economically used instead of water. When nothing more can be extracted, the refuse is sold to the manure-dealer.



CUTTING OUT AND DISTRIBUTING THE GLUE.

When the glue is thick enough it is drawn off into a vessel called a *settling-back*, and maintained at the temperature necessary to keep it liquid.

Here the solution deposits its solid impurities, and is further clarified by the addition of substances which vary according to the skill or judgment of the manufacturer. The glue is next run off into wooden coolers, which are about six feet long, one foot broad, and two feet deep, where, as it cools, it gradually hardens into a tolerably firm jelly. It is then cut out by a spade into square cakes, each of which is placed in a sort of wooden box, open in several slits or divisions to the back; the glue is cut into slices by passing a brass wire, attached to a kind of bow, along the slits. The slices thus formed are placed upon nets stretched in wooden frames, and removed to the glue-maker's field.



GLUE-MAKER'S FIELD AT BERMONDSEY.

The frames, as they are filled, are placed in piles with an interval between every two frames, so that the air may have free access to them. Each pile is covered with a roof to protect it from the weather. The glue is turned two or three times a day, for which purpose the roof is removed, and the uppermost frame placed on the ground. The cakes being turned one by one, a second frame is placed upon the first, and the cakes on it turned in like manner; this goes on until a new pile is formed near the spot where the old one stood.

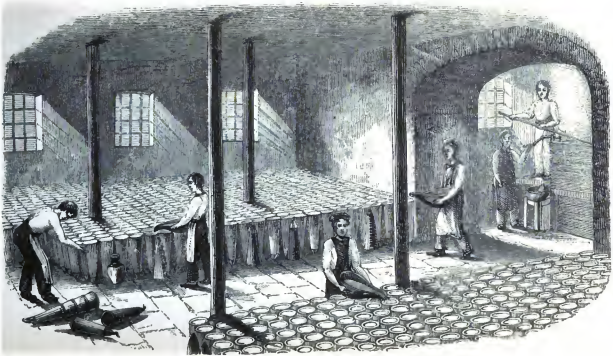
The drying of the glue is the most anxious and uncertain part of the manufacture. A material change in the weather may greatly injure it. If the air becomes very warm, the cakes may become so soft as to lose all shape, or they may even unite with the strings, so as not to be removed without dipping the net in boiling water; or they may even melt entirely, and flow out of the frames. On the other hand, a sudden frost may freeze the water in the glue and cause it to crack in all directions, rendering remelting necessary. A thunder-storm sometimes prevents a whole field of glue from hardening; a fog will sometimes cause a general mouldiness; a wind too hot or too dry, by making it dry too rapidly, may render it unsightly and unfit for the market. Hence it is important to select the most temperate season of the year for the manufacture.

When the glue is about three parts dry it is removed from the open air into lofts, where in the course of some weeks or months the solidifying is completed. During this time the surfaces become mouldy and otherwise soiled, they are therefore scoured with a scrubbing-brush in hot water, and set up to drain; and lastly, dried in the stove-room at an elevated temperature, which, when they are once solid, only serves to harden and improve them.

SCOURING.

Glue is usually judged of by its strong dark colour, and freedom from cloudy and black spots when held before the light. The best glue swells considerably, but without melting, on immersion in cold water, and renews its former size and properties by drying. In melting glue for use, it should be broken into small pieces, soaked for twenty-four hours in cold water, and then melted very slowly over a fire, keeping it frequently stirred; when prepared in this way, it becomes, when cold, a firm jelly, which requires only a little warming to fit it for use. If spread over wood with a stiff brush, pieces thus joined will, in two or three days, be so perfectly connected, that they will as readily break in any other part as at the junction. Glue must not be used in a freezing temperature.

Other kinds of glue are prepared for particular purposes. Fish-glue, also called *isinglass* and *ichthyocolla,* is prepared from the skins and mucilaginous parts of fish. A strong compound glue is made by infusing during twenty-four hours common glue in small pieces with isinglass in a sufficient quantity of spirits of wine to cover the mixture. Heat is then cautiously applied, and, when melted, a quantity of powdered chalk is added, until the whole is of an opaque white. A strong glue, which will resist water, may also be made by adding half a pound of common isinglass to two quarts of skimmed milk, and evaporating the mixture to a proper consistence.



THE FILL-HOUSE.

Digitized by Google

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

HISTORICAL NOTICES OF THE SUGAR-CANE.

As sugar is most abundantly supplied by the sugar-cane, much interest has been excited respecting the early history of this plant. It has been supposed that the Hebrew word, which frequently occurs in the Old Testament,* and is sometimes translated *calamus*, sometimes *sweet-cane*, means the sugar-cane. It is mentioned for the first time in Exodus, where Moses is commanded to make an ointment with myrrh, cinnamon, *sweet calamus*, cassia, and oil olive. The calamus does not appear to have been a native of Egypt or of Judæa; for in Jeremiah it is mentioned as coming from a far country. "To what purpose cometh there to me incense from Sheba, and the sweet-cane from a far country?" It has been argued, that if the cinnamon mentioned in the passage of Exodus were true cinnamon, it must have come from the East Indies, the only country in the world from which it is obtained; and that it is, therefore, highly probable that the sugar-cane was exported from the same country.

Among the ancient writers of Greece, Herodotus alludes to the "honey made by the hands of men." Nearchus, Alexander's admiral, relates that "the reed in India yields honey without bees." Theophrastus describes three kinds of honey; one from flowers, another from the air, (referring probably to honey-dew,) and a third from canes or reeds. Other ancient writers are more or less precise in their mention of sugar, until we arrive at the time of the Roman Emperor, Nero, when Dioscorides uses the word *saccharum*, or sugar: his description refers to a species of sugar-candy, but he was evidently not aware of the mode of preparing it. He says: "There is a sort of concreted honey, which is called sugar, found upon canes in India and Arabia Felix: it is in consistence like salt, and it is brittle between the teeth, like salt." Seneca was also ignorant of the real character of sugar: he describes it as honey found on the leaves of canes, and produced by the dew or the sweet juice of the cane itself concreting. Pliny describes sugar as brought from Arabia and India: "It is honey collected from canes, like a gum, white, and brittle between the teeth; the largest is of the size of a hazel-nut; it is used in medicine only." Galen, who wrote in the second century, also speaks of sugar; and in the seventh century, Paulus Ægineta quotes an early writer, who describes sugar as "*the Indian salt*, in colour and form like common salt, but in taste and sweetness like honey."

---

* Exod. xxx. 23. Sol. Song iv. 14. Isa. xliii. 24. Jer. vi. 20. Ezek. xxvii. 19.

It appears that, during a long period, the sugar-cane was confined to the islands of the Indian Archipelago, the kingdoms of Bengal, Siam, &c., and that the sugar was imported with perfumes, spices, and other merchandise, to the countries on this side of the Ganges. The traffic in sugar being lucrative, the Indians concealed the knowledge of the sugar-cane: they informed the merchants at Ormus that they extracted sugar from a reed, whereupon many attempts were made to obtain it from the reed-like plants of Arabia; but these were all unsuccessful.

The doubts respecting the real nature of sugar were not resolved until the year 1250, when Marco Polo visited the country of the sugar-cane. On his return, the merchants, who had hitherto purchased sugar at Ormus, repaired to the country of its growth. They brought away the sugar-cane and the silk-worm, and from Arabia Felix these valuable productions passed into Nubia, Egypt, and Ethiopia, where sugar was soon produced in abundance, although its quality was very inferior, from ignorance of the means of preparing the juice. In 1420, the Portuguese introduced the sugar-cane from Sicily to Madeira; and, during the same century, it was probably carried from Spain to the Canaries. So successful was the cultivation, that the sugar of these countries was preferred to any other. The Portuguese also successfully transplanted the sugar-cane to the island of St. Thomas, and other islands on the African coast. Soon after the discovery of the New World, the Spaniards established sugar-works in Hispaniola, or St. Domingo: workmen were sent from the Canaries to manufacture the sugar, and the cane flourished so well, that its produce afforded a large revenue to the mother country. In 1641 the cane was transplanted from Brazil to Barbadoes, and thence to the other West India Islands.

For a long period the use of sugar in England was confined to medicines and feasts; and this continued until 1580, when it was brought from Brazil to Portugal, and thence to our country.

Mr. Porter remarks, that "The merchants who introduced the cane from India certainly neglected to bring, also, the necessary instructions as to the methods of preparing the juice; and the difficulties which the Arabian cultivators experienced, doubtless caused them to try the use of all kinds of ingredients for its purification, and to invent conical vessels for crystallizing and cleansing the sugar." The Venetians introduced the art of sugar refining into Europe, at the end of the fifteenth century. At first they imitated the Chinese, and sold the sugar which they purified in the shape of candy, cleaning and refining the coarse sugar of Egypt three or four times over. They afterwards adopted the use of cones, and sold refined sugar in the loaf. This example was soon followed by the establishment of sugar refineries in all the commercial cities of Europe.

VARIETIES AND SOURCES OF SUGAR.

We are accustomed to associate sugar only with the sugar-cane, yet it is one of the most abundant productions of the vegetable world. It is found in a liquid state in most plants; it is manufactured from beet-root, from the sap of the maple, and other vegetable bodies; and this wide distribution of so valuable an article of food is one out of the many instances of the bounty of Providence in supplying our wants.

Of the numerous varieties of sugar, some can be made to ferment, others not; some can be formed into crystals, others not; but it often happens that two kinds of sugar are mixed, as in the sugar-cane, the juice of which yields the finest crystals, and also *molasses*, or *treacle.*[*] The size of the crystals, however, depends greatly upon the mode of treatment: when they are rapidly formed, as in common refined sugar, the crystals are small and confused; but when obtained by the slow evaporation of a strong solution, they are large and transparent, as in *sugar-candy*.

Sugar is the principal food of the vegetable world. It exists largely in the succulent parts of plants and seeds when they begin to shoot. It is formed in several kinds of seed in the process of *malting*, which consists merely in steeping seeds in water until they sprout. In the ripening of many fruits there is a similar change. When palms are about to flower, the starch contained in their stems is changed into sugar. If plants are allowed to flower, the gum and sugar disappear from the roots or stems: this change applies to such common roots as the parsnep, carrot, beet, &c., as well as to the sugar-cane, maize, and other plants rich in sugar matter. The stems of grasses are also sweet at an early stage of their growth, when they are most nutritious and palatable to cattle, a circumstance which ought to regulate the time for making hay. In certain trees the starch formed in autumn is converted into sugar by the ascending sap in spring, and sugar is formed in considerable quantities from the sugar-maple. The sap of the birch-tree, on being fermented, yields an agreeable beverage, called *birch-wine.*

---

[*] An eminent French chemist is of opinion that the whole of the sugar furnished by the cane might be converted into crystals, molasses being formed, according to his view, by the boiling and other processes which the juice undergoes.

The juice of grapes furnishes a peculiar kind of sugar, called *grape-sugar,* which has been traced in many fruits, such as pears, peaches, cherries, melons, dates, figs, and the chestnuts which grow in warm countries.. Grape-sugar is also formed in the nectaries of many flowers, and is collected by bees; hence *honey* belongs to this variety of sugar.

Grape-sugar can be procured from starch by the action of dilute sulphuric acid. *Lignin,* or *woody fibre,* or any substance containing it, can also be converted into sugar by the same means. If sawdust, linen-rags, paper, or other ligneous substance, be rubbed up with sulphuric acid, and the acid afterwards removed by adding an alkali or some powdered chalk, the ligneous body will be changed into a species of *gum,* which, being boiled for some hours in a weak acid, is gradually converted into sugar.* It has been well observed, that, "however clumsy and inconvenient this process is in our laboratories, being, as we are, but Nature's journeymen, Nature herself carries on these transmutations with the most wonderful results, as we see in the ripening of fruits, when the hard woody texture gradually softens down into sweet and luscious pulp, as in the ripening of the pear, the grape, the strawberry, and in short, almost all fruits."

---

* The conversion of old rags into more than their weight of sugar has been regarded as one of the marvels of modern chemistry; but the wonder ceases on comparing the ultimate composition of lignin, or woody fibre, (of which rags are only an example,) with sugar.

It appears, from Dr. Prout's experiments, that all the varieties of lignin are similarly constituted. 1,000 parts of lignin consist of 500

The above varieties of sugar are granular or crystalline, and are all capable of undergoing the vinous fermentation. The only sugar which refuses to crystallize, but which can be fermented, is the molasses which remains after refining cane and other sugars, and this is largely used in the distillation of rum. *Sugar of milk* and *manna sugar* do not ferment. The former, sometimes called *Lactine*, is obtained by evaporating the whey of milk; the latter, also called *Mannite*, is contained in the manna which exudes from several species of ash: it is also found in the bark of the olive-tree, in some species of pines, in the root and leaves of celery, in the bulb of the onion, in many kinds of sea-weed, and in couch grass. By long exposure to the air the juices of many plants, such as beet, carrot, &c., generate manna sugar.

Sugar is extensively employed to preserve animal and vegetable substances, such as meat, fish, fruits, jellies, and many medicinal substances; and in some cases is preferable to salt in not destroying the true flavour of animal food. The sugar which is naturally formed in many fruits is sufficient to preserve them, as in raisins, figs, and other dried fruits.

In temperate climates sugar is rather a luxury than a necessary of life; but in tropical countries it is extensively used as an article of food, and has been ranked inferior only to corn. Enormous quantities of sugar-canes are sent from the sugar islands to the markets of Manilla, Rio Janeiro, and

---

of carbon or charcoal, and 500 of water. 1,000 parts of cane-sugar contain 421 of carbon and 579 of water. The different varieties of sugar contain variable proportions of carbon and water.

the surrounding countries. The crude plant is called by Dutrone, "the most perfect alimentary substance in nature," and this praise does not seem to be exaggerated when we consider its effects upon the negroes at the time of cane harvest. "The time of crop in the sugar islands," says Mr. Edwards, "is the season of gladness and festivity to man and beast. So palatable, salutary, and nourishing, is the juice of the cane, that every individual of the animal creation, drinking freely of it, derives health and vigour from its use. The meagre and sickly among the negroes exhibit a surprising alteration in a few weeks after the mill is set in action. The labouring horses, oxen, and mules, though almost constantly at work during this season, yet, being indulged with plenty of the green tops of this noble plant, and some of the scummings from the boiling-house, improve more than at any other period of the year. Even the pigs and poultry fatten on the refuse."

In separating the sugar from the juice some of the nutritive substances are removed; and it should not be forgotten, that the praises bestowed on sugar by different writers on this subject apply to the fresh juice of the cane, and not to the crystallized sugar in use among ourselves.

THE MANUFACTURE OF SUGAR IN THE WEST INDIES.

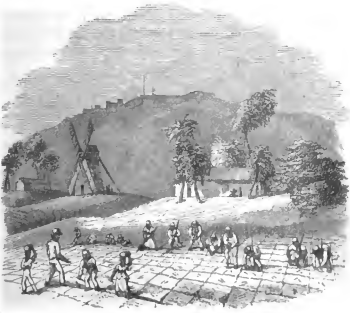
Although the manufacture of sugar in this country consists chiefly in the production of a fine crystalline substance from a raw material, yet no account of sugar can be deemed complete without some account of the plant itself, its cultivation, and the processes adopted, in the countries where it flourishes, for extracting and preserving its juice.

The sugar-cane (*Saccharum officinarum*) is a jointed reed, varying in height according to the species, the character of the soil, and the mode of culture, from three and a half to seven feet, and sometimes from twelve to twenty feet. When ripe, it is of a fine straw colour, producing leaves or blades, the edges of which are firmly and sharply serrated, and terminating in an arrow decorated with a panicle. The joints in one stalk vary in number from forty to sixty, (and even eighty in the Brazil cane,) and the stalks rising from one root are sometimes very numerous. Every joint is furnished with a bud which encloses the germ of a new cane. The young shoot ascends from the earth like the point of an arrow; the shaft of which soon breaks, and the first two leaves rise to a considerable height.

The outer part of the cane is hard and brittle, but the inner consists of a soft pith containing the sweet juice, which at first has all the characteristics of unripe mucous fruits; it afterwards resembles, both in taste and smell, the juice of sweet apples; it gradually loses this, and takes the smell and taste peculiar to the cane.

The torrid zone is most favourable to the growth of the sugar-cane, but it may be cultivated as high as the fortieth degree of latitude. It will not flourish in a merely sandy soil; the best soil is the ashy loam of St. Christopher's, or a mixture of clay and sand, called *brick mould*. Due attention to manuring is of the utmost importance to the success of the cane.

The sugar-cane is propagated by cuttings, which multiply surprisingly. The slips for planting generally include two or three upper joints of the cane, stripped of leaves. These are planted in holes from fifteen to eighteen inches square, and from eight to twelve inches deep, at distances about two feet apart, and in rows three feet apart, spaces being left here and there, for the convenience of carting. Each hole is banked up round its margin with the earth thrown up by the hoe, and manure is put into it. Two or more cuttings are then placed lengthwise in each hole, and are lightly covered up. In about a fortnight the young sprouts appear: some of the earth heaped up round the hole is then put in, and as the plant grows the remainder is gradually added. The young plants are carefully hoed, and all weeds removed. Off-shoots are likewise cut away, because they draw off nourishment from the plants.



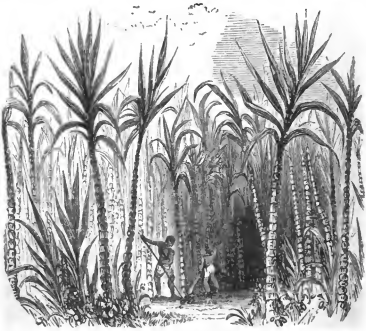
PLANTING THE SUGAR-CANE.

The canes which grow immediately from the planted slips are called *plant-canes;* but it is customary, in the West Indies, to raise several crops from the old roots, or *stoles,* as they are called; and the sprouts from these stoles are named *rattoons,* a corruption of the French word *rejetons* (sprouts).

The above method is subject to many variations, according to circumstances, among which may be mentioned the following :— The slips which are planted in August and September are managed as before till January, when the young plants are cut close to the ground, and the remainder of the mould is spread over the roots, which soon afterwards send forth a number of vigorous shoots of equal growth.

By this method the canes are not too rank in the rainy season, while they come to perfection in good time in the succeeding spring.

The best season for planting is between August and November, and the cane varies from ten to twenty months in arriving at maturity. If the soil be favourable, the canes planted at proper distances from each other, and the land carefully managed, the same plant may continue above twenty years without replanting; but in the common method the lands are sometimes replanted every six or seven years, and in poor soils every two or three.



FIELD OF SUGAR-CANE.

But in spite of all the care of the planter, the sugar-cane is liable to many diseases. The most formidable is called *blast*. It is produced by myriads of little insects, invisible to the naked eye, which feed upon the juice of the cane, in search of which they wound and destroy the vessels. Hence, the circulation being injured, the growth is checked, and it withers or dies. In some of the windward islands a kind of grub, called the *borer*, in dry weather, commits great ravages on the cane. Rats and ants do some mischief, but the latter are more annoying than destructive.

THE CANE HARVEST.

About the month of March or April the cane has attained maturity, as indicated by the skin becoming smooth, dry, and brittle; by the heaviness of the cane, and the juice being sweet and glutinous.

The following description of a field of sugar-canes, at two periods of its growth, is by an eye-witness:—

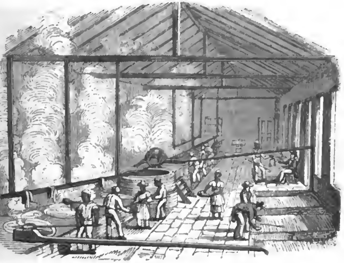
"A field of canes, standing in the month of November, when it is in arrow, or full blossom, is one of the most beautiful productions that the pen or pencil can possibly describe. It commonly rises from three to eight feet, or more, in height; a difference of growth that very strongly marks the difference of soil, or the varieties of culture. It is, when ripe, of a bright and golden yellow, and, where exposed to the sun, is in many parts very beautifully streaked with red; the top is of a darkish green, but as it becomes more dry, from either an excess of ripeness or a continuance of drought, it is of a russet yellow, with long and narrow leaves depending, from the centre of which shoots up an arrow like a silver wand, from two to six feet in height, the summit having a plume of white feathers, delicately fringed with lilac."

In gathering in the canes, they are cut as near the ground as possible, as the lower joints contain the richest juice. One or two of the top joints, in which the juice is not sufficiently matured, are rejected; the remainder are cut into pieces about a yard long, tied into bundles, and conveyed immediately to the mill; for, if allowed to remain long, they would ferment and spoil.

As soon as the canes have arrived at the mill they are crushed between rollers, by which means all the juice is expelled. The rollers are hollow cylinders of cast iron, turned with the greatest care, and fluted with grooves of small depth. They are three in number, and measure from thirty to forty inches in length, and from twenty to twenty-five inches in diameter. They may be arranged either vertically or horizontally, and the middle roller, to which the moving power is applied, turns the other two by means of cogs. The canes are twice compressed between these rollers; for, having passed through the first and second, they are turned round the middle one by a circular skreen, called the *dumb returner*, and forced back through the second and third, an operation which squeezes them completely dry. The cane-juice is received in a leaden bed, and thence conveyed to the boiling-house. The rind of the cane, called *cane-trash*, serves for fuel to boil the juice; and it is also valuable as manure.

The fresh juice is thick, and gummy; of a dull grey, olive, or olive-green colour, and of a sweet balmy taste. It contains numerous solid particles of the cane, most of which can be separated by filtering or by settling. The juice is so fermentable, that, in the climate of the West Indies, it would begin to turn acid within twenty minutes after leaving the mill, unless promptly boiled, and the sugar separated.*

The juice is quickly conveyed into large flat-bottomed coppers, or open pans, called *clarifiers*, which commonly contain from 300 to 400 gallons each. A fire is placed under each vessel, and a syphon, or stopcock, is supplied for drawing off the liquor. When the clarifier is filled with juice, a small quantity of


THE BOILING-HOUSE.

---

* The juice, as it flows from the mill, contains, on an average, eight parts of pure water, one part of sugar, and one part of coarse oil and mucilage, with a portion of essential oil. The object of the subsequent operations is to separate this one part of sugar. In St. Vincent one pound of sugar is obtained from each wine-gallon of the best cane-juice; twenty gallons of juice, of middling quality, afford only sixteen pounds of sugar; and when the juice is watery, twenty-four gallons are required to produce the same quantity of sugar. Peligot says that out of every ten parts of juice nearly two parts are sugar, and that if more scientific methods of separating the sugar were adopted, little or no treacle would be produced.

lime, called *temper*, is added, the object of which seems to be to correct acidity, and also, by rendering the solid impurities insoluble, to cause them to be thrown up into the scum. As the liquor becomes hot, this scum rises to the surface, and shortly before the boiling point is attained it forms blisters, and breaks into white froth. The fire is then extinguished, and the liquor allowed to repose during one hour, when it is carefully drawn off without disturbing the scum, which sinks unbroken, and is removed from the clarifier before another charge of juice is added. In this process, if the juice were allowed to boil, the scum would be broken up, and reabsorbed by the liquor.

The clarified juice, which is of a clear bright yellow wine colour, is next removed to the largest of a series of evaporating pans, which are placed over a large stove, heated by a fire at one end. Here the juice is suffered to boil, and the scum, as it rises, is carefully removed, lime-water being occasionally added if the juice is not clear. When sufficiently reduced in bulk by evaporation to be contained in the second or middle-sized pan, the juice is transferred, and the boiling and scumming repeated until it is sufficiently reduced to be contained in the third or smallest pan, called the *teache*. In this vessel it is boiled down to a thick syrup, which, on cooling, will *granulate*, or separate into grains of sugar. The required consistency is ascertained by taking a small portion of the syrup upon the thumb, then bringing the fore finger in contact with it, and again separating them, noting the length to which a thread of syrup can be drawn before it breaks: if this extends to about half an inch in length, the sugar is judged to be fully boiled. This trial by the *touch* is supposed to give the name of *teache* to the last evaporating pan.

The syrup is next laded or *skipped* into shallow wooden boxes, called *coolers*, each capable of containing about a hogshead of sugar. There the sugar soon *grains*, that is, it forms into a soft mass of crystals imbedded in molasses, which are the uncrystallizable part of the sugar. The molasses are separated in the *curing-house*, to which the soft sugar is next removed. This is a large building, the lower part of which is lined with lead, and forms the molasses reservoir. Over this, on an open framing of joists, are placed the sugar-hogsheads, called *potting-casks*. In the bottom of each cask are bored several holes, an inch in diameter, into each of which is placed either a plaintain stalk or a crushed cane of sufficient length to reach the top of the hogshead. The soft sugar is then removed to these casks and the molasses gradually drain away through the spongy stalks or canes, leaving the crystalline portion tolerably dry. In about three weeks it is fit for shipment. A further drainage of molasses takes place subsequent to shipment, amounting, it is said, to no less than 12 per cent.

Such is the *raw, brown*, or *muscovado* sugar of the West Indies, which is used for domestic purposes, and also by sugar-refiners in making *white* or *loaf* sugar. But there is another kind, very common on the continent, called *Clayed* or *Lisbon* sugar, the produce of the Island of Cuba, the Brazils, and other places. The cane-juice is prepared much in the same way as in the West Indies, until it arrives at the coolers, when, instead of being transferred to hogsheads, it is placed in conical earthen moulds, called *formes*, or *pots*, each of which has a small hole at the point. These holes being plugged up, the moulds are placed with the point downwards, into earthen jars. The moulds are then filled with syrup, and allowed to repose during fifteen or twenty hours. The plugs are next taken out, and the uncrystallized syrup allowed to flow out. The sugar is then pressed down, and the space filled up with powdered white sugar; this being also well pressed down, a quantity of *clay*, mixed with water, is placed upon the sugar, and the moulds are removed to empty pots. The moisture from the clay, filtering slowly through the sugar, carries away the colouring matter and the remaining portions of the uncrystallized syrup. The clay having parted with its moisture is taken off, and renewed several times during about twenty days, when the process is complete. The loaves are then taken out of the moulds, dried gradually in a stove, and afterwards each loaf is divided into three portions: the base of the cone being white, the middle yellow, and the small part brown; these are crushed into coarse powders and packed separately in hogsheads.

MANUFACTURE OF SUGAR IN THE EAST INDIES.

SEVERAL varieties of sugar-cane are cultivated in the East Indies, and the sugar is manufactured by two classes of persons,—the *Ryots*, who cultivate the cane, extract the juice, and boil it down to a thick syrup; and the *Goldars*, who convert the syrup into sugar. The whole of the apparatus used in the processes is very rude and imperfect, and not necessary to be described. The syrup prepared by the ryots is generally called *goor*, and is of various qualities, one of which, in common use for making sugar, is called by the English settlers, *jaggery*. This is produced by first straining the juice, to separate the coarser matters, and then boiling it in a row of earthen pots, placed in mud walls, and lastly, completing the boiling in an iron vessel. When the juice is sufficiently thick, it is poured into earthen pots, where it has much the appearance of honey. But if not intended for the refiner, a little quick-lime is added during the boiling, which enables it to be formed into cakes or lumps, and these are used for domestic purposes, in the same manner as the brown sugar of the West Indies.

The Goldar, who refines the sugar, separates much of the molasses, by placing the jaggery in coarse sack-cloth bags, and subjecting it to pressure (a process which has been patented more than once in England). After this the sugar, which is called *shucker*, or *khand*, is boiled in an alkaline solution, to which a quantity of milk has been added. This is continued as long as any scum rises; it is then evaporated, and sometimes strained, and placed in earthen pots made wide at the top, and terminating at the bottom in a perforated point, which, at first, is plugged with the stem of a plaintain leaf. After being allowed to remain a few days, the holes are opened, and the molasses allowed to drain off. The sugar is improved in quality and colour by covering it with the moist leaves of some succulent aquatic plant, which is equivalent to the process of claying just described. After some days the leaves are taken off, and the upper layer of the sugar, about half an inch thick, which is most purified, is removed and dried in the sun; fresh leaves are applied to the remainder, and thus, by repetitions of the process, occupying from seventy-five to ninety days, successive layers are refined and removed until the whole is complete. This kind of sugar, called *chenee*, is imported into this country.

BEET-ROOT SUGAR.

THE botanical name for beet is *Beta*, so called from a fancied resemblance of the plant, while bearing seed, to the form of the Greek letter *β*. The Germans call it *mangold-wurzel* or *mangold* root, but it is usually pronounced *mangel-wurzel*, which means *scarcity-root.* By a strange contradiction, the French call it *racine d'abondance*, or root of plenty, and also, *racine de disette*, or root of scarcity. There are several varieties of this plant, and one variety, which is extensively grown for the purpose of feeding cattle, is sometimes called *field-beet.*

In the year 1747, a German chemist, named

Digitized by Google

Margraff, discovered that the white beet-root yielded a larger supply of sugar than any other European plant. The subject excited some attention in Germany, and was then forgotten until the commencement of the present century, when Napoleon's scheme for injuring the prosperity of Britain by excluding British colonial produce from France, rendered some method necessary for supplying the French with sugar. Among other plans, that of extracting sugar from beet-root was adopted and encouraged by the government. The plan succeeded, but the cost of the sugar was so enormous, that, on the establishment of peace, in 1814, the ports of France were again opened to West Indian produce, and the beet-root manufacture soon ceased to be carried on. It may be interesting, however, in a work of this nature, to detail briefly the processes adopted under the direction of the best French chemists of the time, for conducting the manufacture.

The first operation is, to clean the roots, which is generally done by scraping with a knife. They are next rasped, and reduced to a pulp by means of a cylinder of tinned iron, from the surface of which narrow plates of iron project, so as to form a series of cutting teeth: the roots are pressed against these plates by a slanting box attached to the frame, on which the axis of the cylinder turns. The pulp is received into a vessel lined with lead, placed below the cylinder. Two cylinders are sufficient to grind down two and a half tons of beet in two hours. This part of the process should proceed rapidly, because the pulp is liable to ferment and spoil. As the pulp is ground it is taken out and placed in strong canvass bags, and the juice, or *liquor*, as it is called, is expelled by strong pressure. The pulp, after being stirred up, is pressed a second, or even a third time. The liquor is allowed to flow immediately into a copper, and heated to 178° Fahr. The strength of the liquor is ascertained by a saccharometer, called a *pèse-liqueur;*

a mixture of lime and water is then stirred in, and the heat increased to boiling point. A thick glutinous scum rises to the surface, and when clear bubbles rise through this scum, the fire is put out. The scum hardens on cooling, and the sediment being deposited the liquor becomes clear and of a light straw colour. The scum is then carefully skimmed off, and the liquor remaining in it pressed out. A cock, placed about five inches above the bottom of the boiler, is next opened, and the clear liquor drawn off. A lower cock lets out a further portion until it appears cloudy: the remainder is boiled again with the liquor extracted from the scum. The clear liquor is then evaporated in a wide shallow boiler to a certain degree of thickness, as indicated by the *pèse-liqueur*, when animal charcoal is added. The boiling is continued until a regular syrup is formed, after which it is strained through a linen bag. This syrup is again boiled and skimmed until it is sufficiently concentrated for crystallizing, which is judged of by the *touch*. The syrup is then transferred to a cooler, and, as soon as crystallization commences, it is beaten up and laded into sugar-loaf moulds, which are removed to the coolest part of the premises. As crystallization proceeds, the crust formed on the surface is frequently broken, and the whole is stirred until the crystals are collected in the centre; it is then left undisturbed. In three days the pegs at the points of the moulds are taken out, and the molasses allowed to drain off, which they do in about a week. White syrup is then poured over the base, which filters through the mass, and carries off much of the colouring matter. The remaining processes are similar to those described further on, under the head of "Refining."

When this sugar is refined, it is impossible to distinguish it, either by the taste or appearance, from refined cane-sugar, and hence arose the practice of smuggling large quantities of colonial sugar into France, and selling it as beet-root sugar. Indeed, Chaptal, after an experience of twelve years, came to the conclusion that beet-root sugar does not differ from cane sugar, either in colour, taste, specific gravity, or crystallization. He found that 5 tons of clean roots yield about 4½ cwt. of coarse sugar, which produce 160 lbs. of double refined sugar, and 60 lbs. of imferior lump sugar; the remainder is molasses, from which a good spirit is distilled. The expenses of the manufacture, however, are so high, that, in a commercial point of view, beet-root sugar can never compete with cane sugar.

MAPLE SUGAR.

In the Philosophical Transactions of the Royal Society, for 1720 is a paper by Paul Dudley, entitled "An Account of the Method of making Sugar from the Juice of the Maple-tree in New England." This is the earliest notice of a method of procuring sugar, which is still practised in many parts of the United States. During the American revolutionary war, the supplies of West India sugar being for the most part cut off, maple sugar was made in large quantities.

The sugar maple (*Acer saccharinum*) grows plentifully in the United States. Its sap is obtained during the months of February, March, or April, according to the season, by boring holes in the trunk in a direction inclining upwards. The south side of the tree is preferred for boring, and the holes, two or three in number, are made at a height of about twenty inches from the ground. The holes are made to penetrate about half an inch into the alburnum, or white bark. A tube of elder or sumach is inserted into each hole, and the sap trickles from this into a vessel placed beneath. The quantity yielded by a tree varies considerably, but the most favourable season for collecting it is when the difference between the heat of the day and that of the night is greatest.

From two to three gallons are considered as the daily average afforded by a single tree; but as many as twenty gallons have been obtained from one tree in one day. The sap is very liable to ferment, and must therefore be boiled down speedily. This is done by a rude apparatus erected in the encampment of the sugar-makers. The syrup is evaporated to about one-third of its original bulk, the scum being removed. A small quantity of butter, or fat, is thrown in during the last boiling. The molasses are separated in an imperfect manner by filtration. The sugar is said to be equal to cane sugar, and cannot be distinguished from it in the refined state.

SUGAR REFINING.

The processes by which raw or brown sugar is converted into white sugar are of a striking and interesting character. Of late years they have been subject to considerable improvement, and they now partake largely of the scientific character of our most important manufactures.

The principal sugar refineries of London are situated in Whitechapel and its neighbourhood: most of them are extensive buildings, each consisting of seven or eight stories; the rooms, or *working-floors*, as they are called, present a singular appearance. Each floor is paved with stone, is of small height, and the ceiling is formed of brick arches, supported on iron pillars; the object being to render the building fire-proof and of great strength, and also to provide an extensive surface for arranging the sugar in the different stages of the process. A square opening is left at the side of each floor, over which, in the top floor, is a crane, for the purpose of removing the sugar as occasion requires.

The reader may perhaps be able to form a tolerably accurate idea of the art of sugar refining, from the following attempt to trace the sugar from its raw to its refined state. The description applies to an extensive refinery at Whitechapel (Messrs. Fairrie's), which, in company with an artist, the writer was privileged to visit.

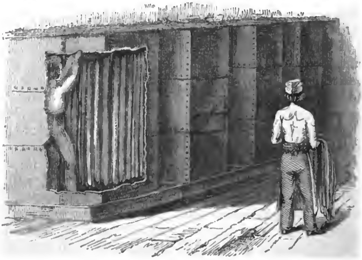
Sugar from the West Indies is packed in hogsheads, and that from the East Indies in canvass bags, covered with matting. These are received into the first floor of the refinery, situate a little above the street, where they are broken open and unpacked by the side of a large circular vat or cistern, which is pouring forth clouds of steam, and filling the floor with an oppressive sickly vapour. In this cistern the sugar is first mixed with water, with the addition of a small quantity of lime-water and bone-black. Heat is applied by means of steam, which issues from a number of small copper pipes contained at the bottom of the vessel, and from this method of applying heat the vessel is called the *blow-up cistern*, the

BLOW-UP CISTERNS.

steam forcing itself by its own pressure, or *blowing up*, through the mixture. The perfect solution of the sugar is promoted by stirring with long poles. Shortly before the liquid has attained the boiling point, it is allowed to flow along a channel into a filtering apparatus, situated in the room beneath; on leaving which it appears as a clear reddish syrup.

The chief object of this process is to separate mechanical impurities, such as dust, dirt, &c., from the sugar. Until within a few years the process was conducted in a ruder and a far less direct manner. The raw sugar, mixed with lime-water, was heated in a large open copper by a fire from below, and when warm a considerable quantity of bullocks' blood, technically called *spice*, was stirred in. The serum or watery part of the blood (consisting chiefly of albumen, of which white of egg is a familiar example) becoming curdled by the heat, and entangling most of the impurities floating in the solution, raised them to the surface in the form of a thick scum, which was carefully removed. This process was sometimes repeated two or three times, with fresh quantities of blood, and from the scummings a low quality of sugar was afterwards obtained. The liquor being thus clarified, was filtered through a thick woollen cloth, and afterwards boiled in an open copper until sufficiently concentrated for graining. So imperfect was this method, that in order to produce loaves of the finest quality, a second refining was necessary; the loaves first produced were broken up and re-dissolved, and clarified with white of egg; this being carefully skimmed off, a small portion of indigo was added, the effect of which was to neutralize the yellow colour of the syrup. These costly methods, which of course greatly increased the price of sugar, are now rendered unnecessary; for, in the modern process, a clear liquor is obtained without the aid of so offensive a substance as bullocks' blood, a portion of which generally became entangled with the sugar, and was not separated by crystallization.

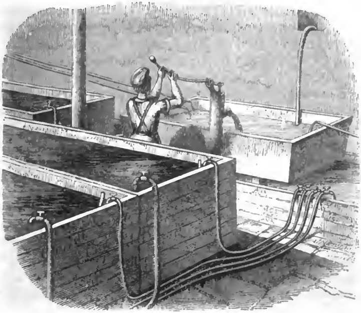
The filtering apparatus now in use is arranged in an ingenious manner. It consists of square vessels of iron, about eight feet high, connected with cisterns above and below, and containing a number of twilled cotton cloth tubes, closed at their lower ends, but open at the upper ends, which are screwed into the floor of the upper cistern. Within each tube is a bag of cotton cloth, which, being considerably wider than the tube, hangs down in folds. About sixty tubes, thus arranged, are contained in each filter, so that by this means an extensive filtering surface is obtained; the liquor from above, having to pass through the meshes of the cloths, is strained of most of its solid impurities, and a clear reddish syrup drops into the cistern below. The bags soon become clogged up, and are frequently removed for the purpose of being cleansed. A black viscid mud is scraped off, but, as this contains a portion of saccharine matter, it is again boiled and otherwise treated before it is transferred to the dealers in manure.



BAG FILTERS.

It is obvious that, in order to produce white sugar, the syrup or liquor must be without colour. When it leaves the filters it is of a dark-red colour, and to remove this is the object of the next process, the introduction of which is one of the great modern improvements in the art of sugar refining.

Chemists have discovered the existence of a remarkable attraction between animal charcoal and the colouring matters furnished by animal or vegetable substances. This kind of charcoal (or as it is sometimes called, *bone-black*, or *bone-charcoal*) is produced by heating bones to redness in a close vessel, or when covered over with sand. The bones lose about half their weight by being calcined; they are then pounded in a mill into a coarse granular state like gunpowder, in which they are fit for use.



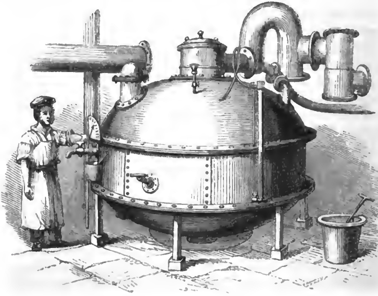
CHARCOAL FILTERS.

The charcoal filters at Messrs. Fairrie's are oblong vessels, about five feet in height, furnished with a double bottom, the upper one being pierced with holes, and covered with cloth to prevent the holes being choked up and the particles of charcoal being carried away by the liquor. The charcoal is heaped up on this cloth to the depth of three feet, and the reddish liquor from the cistern above is allowed to flow in a gentle stream over the surface; it slowly sinks through the mass, gradually losing its colour, until it arrives at the space below, when it is colourless. A series of pipes and syphon tubes from the various "charcoal cisterns," as they are called, conveys the filtered liquor into reservoirs, whence it is pumped up to the sugar-boiler in the room above.

In the course of a few days the charcoal becomes foul and unfit for use. Water is passed through it to remove all saccharine matter, and it is then taken to the retort-house and re-calcined, a process which restores all its valuable properties.

The next process which the liquor undergoes, namely, the boiling preparatory to crystallizing, is one of the most important in the whole range of operations to which the sugar is subjected. By the old method the syrup was concentrated in open pans, standing over fires, and heated to 240° or 250° Fahr. This high degree of heat was very injurious to the sugar, for it changed a large portion of it into treacle, which had to be got rid of in the moulds. The method was also objectionable on account of its danger, and the difficulty of managing the heat. Many plans were adopted for heating the liquor, by passing steam pipes through it, or hot oil under it, but they were all superseded by the valuable invention of the Honourable Edward Charles Howard, now in general use under the name of Howard's vacuum-pan, first introduced in 1813. The principle of this invention rests on the fact, that the boiling points of all fluids are considerably lowered by placing them in vacuo. Thus, under ordinary circumstances, water boils at 212°, the pressure of the air, which is equal to about fifteen pounds on every square inch of surface, preventing the rapid formation of vapour at a lower temperature; but if water, at the temperature of 90° or 100°, be placed under the receiver of an air-pump, and the air be exhausted, the water will boil rapidly and pass off in vapour. The object, therefore, which the inventor of the new method had in view was to collect a sufficient quantity of syrup in a closed vessel placed in connexion with an air-pump; then to remove the air, and apply a very moderate degree of heat, by which means the syrup could be boiled at a low temperature, and brought down to the granulating pitch. After numerous trials and failures the inventor was rewarded with success. and continued during several years to derive a large income from premiums paid by sugar refiners for permission to use the patent process. The patent having now expired, no restriction is placed upon its general use.

The vacuum-pan consists of a large copper vessel, about six feet in diameter, supported on legs, so that every part may be conveniently inspected. The lower part of the pan is double, for the purpose of letting in the steam which is used to heat the syrup: within the pan, in contact with the syrup, is a coil of copper pipe, through which also steam is passed. The bottom cavity, or *steam-jacket*, as it is called, is supplied with low-pressure steam, but the spiral pipe is filled with high-pressure steam, which is considerably hotter than boiling water, and greatly promotes the evaporation of the syrup. From the centre of the dome rises a neck, which, by means of a bent tube and other apparatus, connects the interior of the pan with the air-pump used for extracting the air and vapour. The interior of the pan is also connected by means of pipes with vessels containing the clarified syrup, which may be situated in the upper stories, or in the charcoal-filtering room below. In the former case, the syrup runs down into the pan on turning a stop-cock in the pipe, and in the latter case it rises by atmospheric pressure, as soon as a partial vacuum is formed in the pan. The pan is furnished with a barometer or manometer, for showing the state of vacuum, and also with a thermometer, for indicating temperature. There is also a cistern-pipe, for receiving any syrup that may accidentally boil over; but the too rapid boiling, and also the danger arising from the pressure of the air on the outside, which might crush in the pan, are prevented by a safety-valve, which admits air in case the exhaustion should at any time be made too perfect. There are numerous other minor details, which need not be particularized.



THE VACUUM-PAN.

The pans generally contain each about 100 gallons of syrup, which yield about eleven cwt. of granulated sugar at every charge. Sometimes the pans are of larger dimensions. Dr. Ure mentions one in use at a London house, which works off eighteen tons of sugar-loaves daily.

The pans being properly charged, and steam admitted within the steam-jacket and the coiled pipe, the air-pump is set in action, its moving power being supplied by the steam-engine of the establishment; the syrup soon attains a temperature of about 130°, when it boils, and throws off vapour of water, which is pumped off, and condensed in a vessel placed in the open air, over which a stream of cold water is constantly flowing. As the syrup becomes more concentrated, its boiling point becomes higher: the temperature is, therefore, gradually raised to about 150°, which is about 100° lower than would be required for open vessels. The attendant is enabled to watch the process by means of a very ingenious contrivance, called a *proof-stick.* This consists of a cylindrical rod, exactly fitting a hollow tube which enters the pan in a direction slanting downwards. The upper end of the rod is open; the lower end, which dips into the syrup, has a slit on one side of it, about half an inch wide. Within this tube is another shorter tube, which can be moved round in it through half a circle: near the lower end of this tube is a hollow which corresponds with the slit in the outer tube; and the upper end is connected with a handle. By making the slit and the cavity coincide, the latter is filled with sugar; then, by turning the stick round through half a circle, the slit is covered by the fixed tube, and the inner tube can then be withdrawn without allowing air to enter the pan.

THE PROOF-STICK.

The sugar is tried by the *touch*, as already explained: the small crystals which appear in it are examined, and the moment the liquor has attained the granulating pitch, the connexion of the pan with the air-pump is cut off, air is admitted to equalize the pressure, and a plug at the bottom of the pan is opened, by means of a lever attached to it, when the whole of the syrup flows down a pipe into a receiver situated in the room below.

Digitized by Google

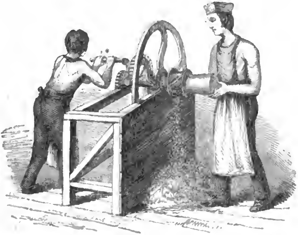
In our notice of the process of sugar-boiling in the West Indies, it was stated that, as soon as the syrup was boiled down to the point of granulation, it was transferred to a vessel called a *cooler*, the process of boiling in open vessels raising the liquor to so high a temperature, that cooling is absolutely necessary to crystallization. The introduction of the vacuum-pan has wrought a curious change; for, after the boiling is complete, the syrup is removed, not to a *cooler*, but to a *heater*, where it is raised to the temperature of 180° or 190°, the object being to make the syrup more fluid than the comparatively low temperature of the pan admits of, and also to prevent crystallization before the sugar is poured into the moulds; for, were this to take place, the colouring matter would be so imbedded in the mass of crystals, that no after treatment, short of remelting, would get rid of it. Not only, therefore, is the temperature of the syrup raised, but men are employed with poles in beating and stirring it up, while it is being removed to the moulds.

The heater is a shallow vessel of copper, surrounded with an iron steam-jacket for keeping up the proper degree of heat. The syrup which flows into it from the pan is no longer a limpid, colourless fluid, as it was in the filter-cisterns; it is now exceedingly thick and viscid, and the process of boiling has concentrated the colouring matter, the molasses, and uncrystallizable parts of the sugar, to get rid of which is one of the objects of the concluding processes.

The sugar is next removed to moulds in the *fill-house*, which is situated in the lowest story, and on a level with the heater. The conical sugar moulds are made of brown earthenware, or of sheet iron well covered with paint; the pointed ends are open; and the moulds vary in size according to the quality of the sugar, the largest moulds being used for the inferior sorts. At the time of the writer's visit to the fill-house, one set of men were engaged washing the moulds, and putting them up in piles to drain. A second set rolled these piles to another part of the floor, and placed them one by one, with their points upwards; a third set were occupied in twisting pieces of paper, with which they plugged up the holes in the moulds; a fourth set were setting up the moulds, point downwards, an operation simple in appearance, but requiring a level floor, and that kind of ready skill which can only be attained by long practice. Beginning at one corner, the moulds were arranged in ranks, four or five deep, along the whole length of the floor. A fifth set of men, eight or ten in number, were engaged in filling the moulds; each man was naked from the waist upwards, and was furnished with a copper basin, which he filled at the heater by opening a kind of sluice at the side, and then with a rapid step conveyed the syrup to the moulds, and poured it into them. Each man carried enough to fill one mould, and about half of another. A sixth set of men immediately stirred round the sugar in the moulds, to diffuse the crystals equally through the viscid mass. In this way the filling proceeded until the contents of the heater were exhausted, and as the moulds were filled, fresh rows were arranged in front of the former; until at length a considerable portion of the extensive floor was occupied. Part of this busy scene is represented in the frontispiece.

Matters remain in this condition until the next day, when the sugar has become partially solid: the moulds are then moved through the *pull-up hole* into an upper floor, which is maintained, by means of steam-pipes, at a temperature of 80°; the paper plugs are removed, and a wire is passed through the hole to ensure an open channel; the moulds are then set in earthen jars, or are hung in a frame work over a gutter terminating in a sunken cistern. The syrup which flows off is of a greenish colour, and being collected and reboiled with raw sugar, it produces an inferior quality of lump sugar; this again furnishes a syrup, which supplies a yet lower description of sugar, and when all the crystalline particles have been removed, the residue is sold as *treacle.*

In the course of two or three days the drainage is complete: but there still remains a portion of syrup and uncrystalline matter entangled with the solid sugar. To get rid of this, a process of washing is adopted, which, under the old method, was performed by *claying*, as already described; but now by a process, one of Mr. Howard's valuable improvements, which accomplishes the work in one-fourth of the time formerly required. Some finely clarified syrup is made by dissolving in warm water loaf sugar, consisting of the turnings obtained by a subsequent process, and such loaves as do not satisfy the critical eye of the refiner, either by their shape or crystalline texture. The syrup thus obtained is poured, to the depth of about an inch, upon the broad part of each cone, the surface of which has been previously broken up and made level by an iron tool called a *bottoming-trowel.* As this syrup is concentrated, it can dissolve none of the sugar already crystallized, but readily unites with molasses and colouring matter which do not crystallize, and gradually drains away with them. The loaf improves in whiteness, from the base to the point, every time this operation is performed. A few moulds are emptied from time to time to examine the success of the blanching; and when the loaves have acquired as much *colour* (as the whiteness is called by the refiners) as is judged necessary, and are sufficiently dry, they are *netted,* that is, made *net,* or *neat,* in appearance. The moulds are taken, one by one, and placed across a trough, and the base scraped with the bottoming-trowel, so as to produce an even surface: this operation is called *brushing off.* A few blows being applied to the mould, the sugar is loosened, and turned out upon its base. If the sugar is of the best quality, it is of a perfectly pure white, from the base to within five or six inches of the point; and here a portion of moisture and colouring matter still remains, which is removed by the process of *turning off*. This is effected by cutting blades, arranged in a conical form, connected with wheel-work, to which motion is given by one man, while another gradually introduces the loaf within the space formed by the knives, whereby the coloured damp portion is removed, and the loaf improved in shape. Loaves of coarser sugar are not turned off, but the damp ends are cut off, leaving them in the form of a truncated cone. The loaves are then removed to an oven, which occupies nearly the whole height of the building, upon a base of not more than ten feet square. This oven is provided with open frames, from the base to the top, upon which the loaves are arranged, and a constant temperature of about 140° is maintained, by a numerous assemblage of steam pipes. When sufficiently dry, the loaves are taken out, tied up in paper, and are then fit for the grocer's shop.


TURNING OFF.

The routine of operations at the refinery takes about a fortnight, during which various qualities of sugar are produced; *first*, white *loaves* of the finest quality, obtained directly from the raw or muscovado sugar; *secondly*, a second quality called *lumps*, composed of the *second runnings*, which are the syrup used in washing the loaves after the *green* syrup is separated; *thirdly*, an inferior quality, composed of the green syrup, mixed with raw sugar, producing what are called *bastards*. These are crushed into powder, and sold as a superior kind of *moist* sugar; *fourthly*, several inferior kinds of sugar are produced from the refuse matter, consisting of the impurities collected in the bag-filters, the scrapings of the various floors, and the *waste*, which in the several departments of an extensive refinery is necessarily great. All these sources of sugar are carefully collected; the crystalline particles separated from the treacle, and this again from dirt, and other impurities, which are finally sold as manure. Every third week the routine is again commenced, and carried on during another fortnight of twelve days; for it is satisfactory to learn that, in this manufacture, Sunday is a day of rest.

SUGAR OVEN.

As some of the different qualities of sugar are being forwarded a stage at the same point of time, the stranger is somewhat embarrassed to notice such various results produced, as it were, by the same means. But on clearly understanding the economy of the refinery, he will be able to trace the pure white loaves, from the raw sugar in the hogshead to its final completion, passing over, as accidental or subsidiary, the various arrangements whereby inferior loaves are produced, or in other words, whereby waste is prevented. In such a case the refinery presents points of the highest interest. It is curious to witness the application of so much science, ingenuity, skill, and capital, to the production of an article which, after all, is one of mere luxury, and, according to Dr. Prout, is inferior in nutritive properties to the raw sugar which furnishes it, a circumstance which may afford some satisfaction to those persons whose means will not allow them to use white sugar. The working floors of the refinery, containing many thousand moulds filled with sugar, are peculiarly striking. The utmost care is taken to guard the sugar from speck or stain, but the floors themselves are not so privileged: during the processes of *filling* and *washing*, small quantities of syrup are being constantly spilt, and this is soon trampled into a thick viscid mud, which adheres to the feet, and in some places actually impedes motion. Heat is every where present, and often to an oppressive degree, but its source is seldom seen; the system of heating by steam has enabled the refiner to regulate the supply of heat as he may desire, and has also rendered perfectly safe a process which was formerly very hazardous. The effect of the various modern improvements has greatly reduced the price of refined sugar; at one time its price was 40 per cent. greater than raw sugar, but now the difference in price is not more than 20 per cent.

SUGAR-CANDY.

One of the oldest methods of refining sugar was to allow the syrup to form large crystals, a plan which is now adopted in the manufacture of sugar-candy. The modern process is as follows:—

The syrup, being properly clarified, is poured into old moulds, within which small twigs are placed, or strings of packthread stretched. As the syrup cools, crystals collect round the twigs or strings, the size of the crystals increasing gradually from day to day. In about nine or ten days the moulds are placed in pots in a hot room; the syrup is allowed to drain off, and the candy is dried. Coloured or perfumed sugar-candy is made by mixing cochineal, indigo, or some colouring matter, or scent, with the syrup.

Candy is the only kind of refined sugar made in China and India. The Chinese are celebrated for it, and export it largely.

Candy is less easily dissolved than loaf sugar, and this does not melt so easily as raw sugar: hence it is said that raw sugar "sweetens better" than the other two: but the greater or less intensity of sweetness seems to depend upon the quickness with which it dissolves; for there cannot be a doubt that when once dissolved, the purer the sugar, the more perfectly is the saccharine principle developed.

STATISTICS OF SUGAR.

The consumption of sugar in different years is liable to great fluctuation, arising from variation in price, and the means of the people to purchase; but it has been calculated that the annual consumption averages about 20 lbs. per head for Great Britain; about 5 lbs. per head for France; 4 lbs. for Germany; and about 2½ lbs. for other parts of Europe.

In the year 1839, the quantity of cane sugar produced in different parts of the world was estimated as follows:—

	Cwts.
The British Sugar Colonies exported	3,571,378
British India “	519,126
Danish West Indies “	450,000
Dutch ditto “	260,060
French Sugar Colonies “	2,160,000
United States of America “	900,000
Brazil “	2,400,000
Spanish West Indies “	4,481,342
Java “	892,475
Exported for internal consumption, exclusive of China, India, Siam, Java, and the United States	2,446,337
	18,080,718

Between one-fourth and one-fifth of this quantity is consumed in the United Kingdom. The quantitiesi mported during three years are as follows:—

	1839. Cwts.	1840. Cwts.	1841. Cwts.
West India, of British Possessions	2,823,931	2,202,833	2,145,500
East “ “ “	518,925	482,824	1,239,738
East “ of Foreign “	722,777	—	803,668
Mauritius	612,586	545,009	716,112
Foreign	722,777	805,179	—

The duty on sugar from British possessions was during many years 24*s.* per cwt.; foreign sugars paid a duty of 63*s.* per cwt. The net revenue from this source, for 1839, was 4,586,936*l.*; for 1840, 4,449,033*l.*; and for 1841, 5,114,390*l.* By a recent act of the legislature the duties payable on the importation of sugar, subject to minor exceptions, depending on reciprocity treaties and other circumstances, are as follow:—

	Per Cwt.
Sugar grown in British West Indies or East Indies—	
Double Refined	£1 1 0
Refined	0 18 8
Clayed	0 16 4
Brown, or Muscovado	0 14 0
Molasses	0 5 3
Sugar grown in other British Colonies—	
Clayed	1 1 9
Brown	0 18 8

Sugar grown by *free* labour in Foreign Countries—			
Clayed	£1	8	0
Brown	1	3	4
Sugar grown by *slave* labour in Foreign Countries—			
Refined	8	8	0
Brown	3	3	0
Molasses	1	3	9

Before these alterations, refined sugar was not allowed to be made in any of our colonies, but was reserved for the advantage of this country: considerable quantities were, therefore, annually exported. In the year ending 25th June, 1840, the chief export of British refined sugar was as follows:—

	Cwts.
To Italy	40,000
" British North America	37,000
" Turkey	30,000
" Russia	20,000
" Australian Settlements	11,000
" British West Indies	10,500

Although foreign sugar paid nearly three times the duty charged on our colonial sugar, yet the refiner was permitted to refine it *in bond* for exportation, a drawback being allowed in the proportion of 34 cwt. of raw to 20 cwt. of refined.

The men engaged in the sugar refinery appear to enjoy average good health. In some of the processes, they are exposed to a warm damp atmosphere, and in others to a hot dry air; but they are not long enough at them to suffer injuriously, the nature of the work leading them to conduct other processes which are rather healthy than otherwise. The preparation of the bone-black is peculiarly disagreeable and dirty,—the air of the room in which it is performed being very hot, and loaded with particles of dust; but this is usually a separate trade.

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

THE MANUFACTURE OF SULPHURIC ACID.

HISTORICAL NOTICE.

It has been well remarked, that between science and the useful arts there subsists a constant mutual interchange of good offices, and that no considerable progress can be made in the one, without giving rise to corresponding steps in the other.

One of the most valuable gifts bestowed by science on the useful arts, is *sulphuric acid,* commonly called *oil of vitriol,* and the history of this substance is a good illustration of the benefits resulting from the progress of chemical science; for just in proportion as this has improved, the manufacturer has been able to produce this valuable acid more abundantly and more cheaply. At one time the means of production were slow and tedious, and the price varied from half a crown an ounce to half a crown a pound: at the present time the market price is about one penny a pound, and the quantity annually produced is probably not less than 60,000 tons, or about 100,000,000lbs., which at ten shillings per cwt. amounts to above 600,000*l.*

This vast quantity of sulphuric acid is employed in various ways. It is used in the formation of Epsom salts (sulphate of magnesia); also in the decomposition of common salt for the production of sulphate of soda, which is afterwards converted into the common carbonate of soda. It is used extensively in the manufacture of chloride of lime for the bleachers; and also in the preparation of colours and mordants in calico printing; also by the alum makers, alum being a salt of great importance in dyeing, colour-making, &c. Sulphuric acid is also largely used in tanning and leather-dressing, for opening the pores of skins, and fitting them for the reception of astringent and colouring matters. It is also used to produce charcoal from treacle, in the manufacture of blacking; and carbonic acid from chalk, in the manufacture of soda-water. It is employed in separating silver from gold; and the sulphate of silver thus produced being acted upon by copper, yields metallic silver, and the copper uniting with the acid, forms sulphate of copper or blue vitriol, which has numerous applications in the arts, as a source of fine metallic green, blue, and brown colours. When sulphate of copper is acted upon by iron, metallic copper is produced; and the iron uniting with the acid, forms sulphate of iron or green vitriol, which is used in dyeing, calico-printing, and colour-making. Sulphuric acid is also used for decomposing nitre, (nitrate of potassa,) in the manufacture of nitric acid, and the bisulphate of potassa which remains (technically called *nixum*,) is employed for cleaning metal work. Sulphuric acid is also employed in making persulphate of mercury, which is used with common salt in the production of corrosive sublimate and calomel (bichloride and proto-chloride of mercury). A large quantity of this acid is used in the preparation of citric and tartaric acids, from lemon-juice and tartar; and also in the preparation of sugar from starch: also in the production of ether from alcohol; in the preparation of phosphorus from bone earth, and it is also used largely in every chemical laboratory.

To supply these and many other enormous demands, sulphuric acid must of course be manufactured on a very large scale. In many cases large works are erected in which sulphuric acid is the only manufactured product; in other cases, where the demand for sulphuric acid is great and constant for the manufacture of other products, this acid is made, not for sale, but for the purposes required in the works. But before we describe the processes actually in use, it will be interesting briefly to trace the steps by which the manufacture has arrived at its present state of efficiency.

Chemistry has been called "the wise daughter of a foolish mother." This "foolish mother" (Alchemy), however, in her search after the philosopher's stone, which was to convert all the baser metals into gold, discovered many powerful compounds, such as acids, alkalies, and salts, which are now of the utmost importance in medicine, chemistry, and the useful arts. The alchemists bestowed particular attention upon all those substances which bore any resemblance, however remote, to gold; and they even supposed that this precious metal formed the yellow colouring matter of sulphur; they therefore endeavoured to combine this substance with certain metallic, earthy, or saline bodies, so as to obtain a preparation capable of effecting what is now known to be impossible, namely, the conversion of one metal into another. Heat of varying intensity was the grand agent of the alchemists; and its application to the salt commonly called green vitriol led to the discovery of sulphuric acid. This important discovery was made by Basil Valentine, a monk of Erfurth in Saxony, about the year 1440. The term *vitriol* was applied by the alchemists to several salts, probably from their resemblance to glass (*vitrum*); and the green vitriol employed by Valentine was distilled in a retort at a red heat, producing an oily smooth-pouring liquid, which he called *oil of vitriol.*

The solid brown-red substance left in the retort was called *caput mortuum vitrioli.**

The vitriol from which Valentine extracted this acid was obtained from an abundant natural product called *pyrites* or bisulphuret of iron, many varieties of which become encrusted with this salt by exposure, while wet, to the atmosphere; the sulphur being converted into sulphuric acid, and the iron into an oxide, by absorbing oxygen, so as to produce sulphate of protoxide of iron, or, as it is more briefly called, *sulphate of iron.* In its state as a salt, it contains a proportion of water, called *water of crystallization;* and in every one hundred parts of the salt, $54\frac{6}{10}$ are sulphate of iron, and $45\frac{4}{10}$ are water.

Valentine's method of obtaining sulphuric acid by the distillation of sulphate of iron, is still extensively practised on the continent, especially at Nordhausen in Saxony. This acid is distinguished by the names of *Nordhausen acid, German acid,* and also *fuming sulphuric acid,* the last name on account of its emitting dense white fumes on exposure to the air. It is extensively used for dissolving indigo, in making what is called *Saxon* or *liquid blue.*

It was further discovered by Valentine, that during the combustion of sulphur an acid vapour is produced, which might be collected in a liquid form by burning the sulphur in a crucible under a bell-glass moistened with water, and so suspended as nearly to touch the dish containing the crucible. After some hours a small quantity of acid was produced, which

---

* Now called *Colcothar,* and is used as a paint. The fixed residue of a distillation was called by the alchemists the *caput mortuum,* and was represented by a *death's head,* under the idea that it was inert and useless; whilst the volatile matter which rose from such dregs, being active and strong, was called the *animus* or *spirit,* and was represented by a bow, denoting strength or power; or, if it happened to be an acid spirit, then by a bow and barbed arrow heads; the bow denoting strength, the arrow heads sharpness and swiftness of action, the barbs denoting the difficulty of extracting the acid from its combination, as barbed arrow-heads were difficult to extract from wounds.

Digitized by Google

was named *oil of sulphur per campanum*, or *by the bell.* The sulphur thus burned in the air, uniting with its oxygen, forms a vapour called sulphur*ous* acid gas, which is readily absorbed by water, forming a solution of sulphur*ous* acid.

The reader is of course aware, that in all chemical combinations the combining substances unite in certain definite proportions, which are represented by certain numbers or *equivalents*, as they are called. Thus 1 part by weight of hydrogen unites with 8 parts by weight of oxygen to form water, which is therefore represented by the equivalent number 9: so that in every 9 grains or ozs. or lbs. of water, there must be 1 grain or oz. or lb. of hydrogen, and eight grains or ozs. or lbs. of oxygen. Now in sulphur the combining weight is 16; and when one proportional of sulphur=16 unites with *two* proportionals of oxygen, $8+8=16$, sulphur*ous* acid is formed, the equivalent number for which is consequently 32. By exposing this to moist air an additional proportional of oxygen is very slowly absorbed, forming with one equivalent of water (sulphur 16 + oxygen 24 + water 9), *mono-hydrated* (or *one-watered*) sulphur*ic* acid, which has a very greedy attraction for more water, and mixes with it in any proportion. As the one-watered acid, however, is much less volatile than water (not boiling below a temperature of 600°), these dilute mixtures can be concentrated by boiling, which drives away the surplus water, but not any of the acid.*

---

* But the acid can never be rendered by this method stronger than the monohydrate above mentioned, which boils at 620° and distils without change. Acid containing less water than this, can only be obtained by the German process of distillation from vitriol. The reason of this is, that the monohydrate (acid 40 + water 9) is a *chemical* compound, *i.e.* has properties *not intermediate* between those of its ingredients. For the anhydrous (or waterless) acid (sulphur 16 + oxygen 24) which is a solid, is extremely volatile, being entirely vaporized below 100°; yet by uniting with one equivalent (or nine parts) of water, (whose boiling point is 212°) it forms a liquid that does not evaporate below 600°. Compounds containing

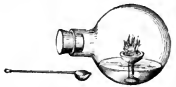
The solution of sulphuric acid obtained by burning sulphur under a bell-glass, was made stronger by boiling in a glass vessel. It was sold at the high rate of 2*s.* 6*d.* per oz., while the common oil of vitriol, from the sulphate of iron, was sold for about the same sum per lb. The higher price was occasioned by the slow and tedious nature of the process; and it was regarded as a wonderful discovery when Homberg, by means of certain improvements in the apparatus, was able to produce five ounces of oil of sulphur in twenty-four hours.

But we must again refer to Valentine for the germ of the modern process of producing sulphuric acid. In a curious work entitled "The Chariot of Antimony," he states that *oil of antimony* may be made by burning equal parts of sulphur, sulphuret of antimony, and nitre, under a bell-glass. Now, nitre or nitrate of potassa, as we shall presently see, causes the sulphur during combustion to receive its highest degree of acidification, and sulphuric acid is at once formed, if water be present.

About the year 1740, two French chemists suggested, that as nitre contains 48 per cent. or nearly half its weight of oxygen in a solid form, if nitre were mixed with sulphur the combustion might be carried on in close vessels, and the quantity of oil of sulphur be thereby increased: an effect which really takes place, even when the nitre is in far too small quantity to supply the oxygen required; for it acts

either *more* or *less* water than this, boil at lower temperatures, but with this difference, that the former give out only their surplus *water*, and the latter only their surplus *acid*; so that though boiling strengthens the one, it weakens the other. At common temperatures, both kinds of acid, however, become weakened, but in different modes; for while the common acid emits *no vapor* whatever, but greedily attracts moisture from the air, the German acid emits *dry acid vapor*, which, meeting with the moisture of the air, instantly combines with it and condenses, forming the white fumes above mentioned; and this continues till both the liquid and the vapour (the former by losing acid, and the latter by gaining water) become reduced to the state of monohydrate or common acid.

in a different manner, which will be explained presently. Dr. Ward acted on this suggestion, and took out a patent for the manufacture. He erected his apparatus at Twickenham, and afterwards at Richmond, near London. He used large glass receivers containing a few pounds of water; these were arranged in a sand-bath with the necks projecting, as shown in the figure. A small stoneware pot was placed in each vessel, supporting a shallow dish, into which a ladleful of sulphur mixed with one-eighth its weight of nitre was introduced. This was kindled by a hot iron, and the necks of the receivers were closed with wooden stoppers. Combustion went on for some time, and the water absorbed the acid vapours. The air in each receiver was then renewed, and a fresh charge introduced. This was done several times, until the water became highly acidulated. It was then drawn off, and concentrated by boiling in glass retorts. A strong acid was thus produced, and sold at what was then the low rate of from 1*s*. 6*d*. to 2*s*. 6*d*. per pound. It was called *oil of vitriol by the bell*, in order that people might suppose it was formed by the combustion of sulphur under a bell-glass as already described.



The use of these large glass receivers was both expensive and dangerous, and served to keep up the price of the acid. Dr. Roebuck, of Birmingham, suggested the use of lead vessels instead of glass, and thus arose the present method of manufacture. The first leaden chamber was erected about the year 1746; but the expense and risk of land carriage (the only means of conveyance at that time) caused the product of the manufacture for some time to be chiefly confined to Birmingham and its neighbourhood. When this acid superseded the use of sour milk in bleaching, sulphuric acid works were established at Preston Pans, on the eastern coast of Scotland. In a few years, in spite of the violent opposition of Dr. Ward, Messrs. Roebuck and Garbett supplied the home demand at a very reduced rate, and also exported large quantities to the continent. In 1756, one of their workmen went to Bridgenorth, his native place, and induced one Rhodes, a seed-crusher, to embark in the business. After this, the method of conducting the process became generally known, and acid works with lead chambers became common.

SULPHUR.*

THE applications of sulphuric acid in the useful arts being so numerous, the consumption of sulphur in a country becomes, as it were, a sort of index of its commercial prosperity. It may therefore be interesting to give a short account of this important substance.

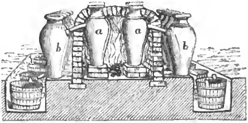
Sulphur is an abundant constituent of mineral substances, forming *sulphurets* when united with metals, and *sulphates* when combined with metallic oxides. It is also very abundant in a free or *native* state, especially in the neighbourhood of active volcanoes, where it is exhaled in large quantities, and condenses in fissures, forming sulphur veins. It is also found in beds. In Sicily, whence our chief supply is obtained, it occurs in beds of a blue clay formation, occupying the central half of the south coast, and extending inwards as far as the district of Etna. One of the excavations made for getting out the sulphur is said to resemble a marble-quarry; the various colours of the sulphur, mingled as it is with clay, calcareous stones, and gypsum, being compared to the veins in marble. The general ground colour is a beautiful shining grey, crossing which, veins of sulphur of various colours are seen; some are much brighter than others; the veins most deeply coloured are nearly red and transparent; the miners call this *virgin* sulphur. The fragments of sulphur, as they are got out, are collected into a heap, and melted in furnaces resembling cauldrons, six or seven feet in diameter, and four or five in depth. A small opening is made in front of each of these, and closed up with moist earth. The largest lumps of sulphur ore are then arranged on a ledge fixed near the bottom of the furnace; smaller masses are next piled up, and still smaller upon these, until a sort of cupola or dome is formed; the irregular spaces are filled up with small lumps of the ore, and lastly, the mere dust of the ore is piled up so as to form a sort of pyramid. The lower part is then covered with fine earth, arranged in a sort of conical belt six or eight inches wide, for preventing the too rapid escape of the fumes after the furnace is lighted. In the course of all this piling up, care is taken to leave a small hole in the top. The fire is applied to this hole by means of a wisp of straw. The outer part of the pyramid first burns, but the fire soon gets to the interior. In about seven or eight hours the sulphur is extracted from the ore, and is found in a liquid state at the bottom of the furnace. The moist earth which closes the hole at the bottom is then perforated, and the liquid sulphur is received into wooden moulds of the form of a large brick. These are first moistened to prevent the sulphur from adhering, and in a quarter of an hour the sulphur blocks can be taken out.

---

* Also called *Brimstone*, from the Saxon *Brenne-stone* or burning-stone.

A more economical form of furnace for distilling the crude sulphur is shown in the annexed figure. Two rows of earthen pots, *a a*, are arranged in a close furnace upon supports, so that the necks of the pots can be let in to the top of the furnace, leaving the mouths free; the pots can thus be charged from without, which being done, they are closed by lids cemented on; the fire is then lighted, and the distillation commences. The sulphur vapours pass over by the side tubes to the receivers on the outside, *b b*, where they condense to liquid sulphur, which flows from thence into tubs of water in which it cools.

The *crude sulphur* thus produced still contains a small amount of earthy matter, which may be got rid of by a second distillation in an improved form of apparatus, so contrived as to produce either roll sulphur, or flowers of sulphur. In this country, however, the *stick* or *roll sulphur* is chiefly obtained during the roasting of copper ore, (sulphuret of copper,) and in other places from iron pyrites (sulphuret of iron). During the roasting of the ores the fumes are received into a long brick chamber, where the sulphur is gradually deposited; it is afterwards purified by melting in pots, when some of the impurities rise to the surface and are skimmed off, while the others sink to the bottom; the purer portion is then poured into cylindrical moulds of beech-wood previously soaked in water.



Flowers of sulphur is the third form in which sulphur is commonly met with. The name was given by the alchemists from a fancied resemblance between this form of sulphur and the light flocculent parts of the flowers of plants. This form of sulphur is obtained by a process called *sublimation,* whereby a solid is converted into a vapour by heat, and then suddenly solidified by cold. It differs from distillation in this, that the vapour *distilled* is condensed by cold so slowly as to become first a liquid.[*] Sublimed sulphur is prepared by heating sulphur in a vessel which communicates with another of large capacity, in

---

[*] The formation of *snow* and *hail* will exemplify these two processes on a great scale.

Digitized by Google

which the vapour is condensed in the form of an impalpable powder of a bright yellow colour.

Sulphur has some curious properties. If a small piece of roll-sulphur be ground in a dry Wedgwood-ware mortar, the powder will adhere to the mortar, in consequence of the electricity developed, so that the mortar may be inverted without losing the sulphur. If a roll of sulphur be grasped in the hand, it splits to pieces with a cracking noise, in consequence of its unequal expansion under a very slight heat. Sulphur fuses at about 216°. On increasing the heat to between 230° and 280° it becomes perfectly liquid, and its colour changes to yellowish brown; but it is a remarkable and unexplained fact, that on increasing the heat to about 320° it becomes thick and pasty, and acquires a reddish tint. Its greatest degree of tenacity is between 428° and 482°. From the latter temperature to its boiling point it again becomes liquid, but not nearly so liquid as it was at 248°. At 600° it boils away in the open air, becoming a transparent orange-coloured vapour, and, if pure, leaves no residue. If at 428° it be poured into water it becomes a ductile mass, capable of being drawn out into very long threads, and may also be used for making casts, and receiving impressions of seals, &c.

The following table, by Dumas, shows the influence of heat upon the colour, &c. of sulphur:—

Temperature.	Heated Sulphur.	When suddenly cooled by plunging it into water.
230°	Very liquid, and yellow	Very friable, but of the usual colour.
284°	Liquid; deep yellow .	Ditto, ditto.
338°	Thick; orange yellow .	Friable; the usual colour.
374°	Thicker; orange . .	At first soft and transparent, then friable and opaque; colour as usual.
428°	Viscid; reddish . . .	Soft; transparent; and of an amber colour.
464° to 500° .	Very viscid; brown red	Very soft; transparent; reddish.
Boiling point .	Less viscid; brown red	Very soft; transparent; brown red.

Fused sulphur crystallizes on cooling. A crystalline arrangement may be seen in the centre of a roll of sulphur; but fine crystals may be obtained by the following contrivance. Melt several pounds of sulphur in an earthen crucible, and when partially cooled, pierce the outer crust in two places at opposite points near the edge; then tilt the crucible so that the melted sulphur below the crust may flow out at one hole while the air enters at the other hole. If the hollow mass be now left to cool slowly, and then be broken open, sulphur crystals will be found within. The sulphur must not be heated so as to become pasty, but must be removed from the fire as soon as it is quite fluid.

Sulphur is quite insoluble in water, but boiling oil of turpentine dissolves it, and the solution is of a reddish brown colour. The specific gravity of sulphur is 1.99, or nearly twice as heavy as its own bulk of water. It emits a peculiar smell when rubbed.

The chief demand for sulphur is in the preparation of sulphuric acid and gunpowder. A large quantity, however, is used for making brimstone-matches and lucifers (of which not less than five thousand millions are annually consumed in Great Britain). Congreves and fireworks also consume a large quantity. It is also used in medicine; in the manufacture of vermilion, which is a compound of sulphur and mercury; also in cementing iron bars in stone; and for bleaching straw and flannel, and for disinfecting apartments by its burning fumes.

In the year 1820 the consumption of sulphur in Great Britain was only 5,000 tons; in 1836 it was about 32,000 tons; in 1838 it was 44,000 tons; nearly all of which was procured from Sicily. About this time the Neapolitan government, in direct opposition to commercial treaties entered into with Great Britain, endeavoured to establish a monopoly in the sulphur trade of Sicily, the consequence of which was a rise in price from 6*l.* or 7*l.* to 13*l.* or 14*l.* per ton. In 1839 the importation into Great Britain had declined to 22,000 tons, of which only 5,400 came direct from Sicily. Through the interference of the British government the monopoly was abolished in 1840, and the sulphur trade placed on the usual footing. The attempt, however, at monopoly had a very injurious effect on the sulphur trade of Sicily, and is well explained in the following remarks by Liebig:—

"Reflecting on the important influence which the price of sulphur exercises upon the cost of production of bleached and printed cotton-stuffs, soap, glass, &c., and remembering that Great Britain supplies America, Spain, Portugal, and the East with these, exchanging them for raw cotton, silk, wine, raisins, indigo, &c., we can understand why the English government should have resolved to go to war with Naples, in order to abolish the sulphur monopoly which the latter power attempted to establish. Nothing could be more opposed to the true interests of Sicily than such a monopoly; indeed, had it been maintained for a few years, it is highly probable that sulphur, the source of her wealth, would have become perfectly valueless to her. Science and industry form a power to which it is dangerous to present impediments. It was not difficult to perceive that the issue would be the entire cessation of the exportation of sulphur from Sicily. In the short period that the sulphur monopoly lasted, fifteen patents were taken out for methods to obtain back the sulphuric acid used for making soda.* Admitting that these fifteen processes were not perfectly successful, there can be no doubt that it would ere long have been accomplished. But then in gypsum (sulphate of lime), and in heavy spar (sulphate of barytes), we possess mountains of sulphuric acid; in galena (sulphuret of lead), and in iron pyrites, we have no less abundance of sulphur. The problem is, how to separate the sulphuric acid or the sulphur from these native stores. Hundreds of thousands of pounds' weight of sulphuric acid were prepared from iron pyrites while the high price of sulphur consequent upon the monopoly lasted. We should probably ere long have triumphed over all difficulties, and have separated it from gypsum. The impulse has been given, the possibility of the process proved; and it may happen in a few years that the inconsiderate financial speculation of Naples may deprive her of that lucrative commerce."

---

* See page 35.

SULPHUROUS AND SULPHURIC ACIDS.

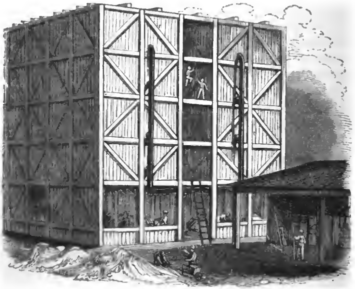
When sulphur is heated in the open air to about 570° it catches fire, and burns with the well-known bluish flame. During the combustion a pungent suffocating gas is produced by the union of equal weights of sulphur and the oxygen of the atmosphere, or one equivalent of the former, and two of the latter, forming *sulphurous acid*. When collected in any quantity, this gas is fatal to animal life, and hence its use in fumigating apartments for the purpose of killing moths and other insects. As this gas extinguishes the flame of most combustibles, it is useful in putting out the burning soot of a chimney on fire, for which purpose a handful of sulphur thrown into the grate has been found sufficient. Sulphurous acid also possesses bleaching properties, by destroying the colours of many vegetable and animal substances: hence its use in whitening woollen goods, silk, isinglass, and the straw used in the straw-hat manufacture. The articles to be bleached are hung in a damp state on strings across a close chamber, in the corners of which are braziers of burning sulphur; all the openings are carefully stopped with wet clay during the *sulphuring*, except a hole for admitting

Digitized by Google

air and another for the escape of the used gases. Rather more than two pounds of sulphur are required to bleach 100 lbs. of silk. Fruit stains can be removed from linen in this way. This gas is also used for altering the colour of hops; for preventing too rapid fermentation in wine vats; and for impregnating casks in which wine, beer, and other fermented liquors are to be preserved, in order to prevent acetous fermentation.

Thus it will be seen that sulphurous acid (sulphur + 2 oxygen) can be produced and applied simply by burning sulphur in contact with atmospheric air. Sulphuric acid (sulphur + 3 oxygen) is by no means so easily produced, however simple it may appear in its composition. In fact, it is in order to make the sulphur in burning take up *three* instead of *two* proportions of oxygen, that the extensive and costly arrangements of a sulphuric acid manufactory are required. A person who inspects these arrangements should have good lungs; for however well managed the works may be, there is generally an escape of acid acrid vapours, the effects of which are evident on surrounding vegetation. The most conspicuous object on entering the works is the large timber erection, or chamber, into which the fumes of burning sulphur are thrown. These chambers, or *houses* as they are sometimes called, vary in dimensions in different works from 60 to 200 feet in length, and of proportionate height and width. They are raised eight or ten feet from the ground by means of brick piers, and are internally lined with sheet-lead, that being one of the few substances not corroded by sulphuric acid at common temperatures. The sheet-lead which covers the bottom of the chamber weighs from 8 to 10 lbs. per square foot, but lead of half that thickness is sufficient for the top and sides. It is necessary to use melted lead to solder together the edges of the sheets, because solder containing tin would soon be corroded. The thick lead which covers the bottom is turned up at the sides so as to form a large tray, or trough, about a foot deep. In some works the floor is divided into compartments by leaden ridges, each compartment having its own exit-pipe for drawing-off the acid; and in some cases the whole chamber is divided into compartments by means of leaden curtains, the form and use of which will be explained presently.

The substances used in the production of sulphuric acid are four. 1. Sulphurous acid, produced by the combustion of sulphur in air. 2. Nitric, nitrous, or hyponitrous acid, from which the sulphurous acid obtains an additional proportional of oxygen. 3. Atmospheric air (1 free oxygen + 4 nitrogen), which must be constantly renewed. 4. Water or steam, for the purpose of dissolving and retaining the sulphuric acid as fast as it is formed.



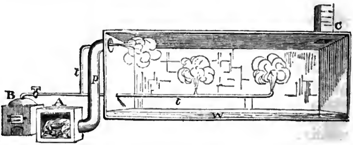
SULPHURIC ACID CHAMBER.

The sulphur which supplies the sulphurous acid is burnt in a small furnace situated at one end of the chamber. Immediately over the burning sulphur is

Digitized by Google

suspended an iron pot containing nitre mixed with the quantity of sulphuric acid necessary for its decomposition. One hundredweight of sulphur requires from eight to ten pounds of nitre, and from five to six pounds of sulphuric acid. The heat of the burning sulphur drives off the nitric acid from the nitre, and the sulphurous acid and nitric acid vapours are carried by a wide leaden tube proceeding from the furnace into the chamber where these vapours meet with steam, which is admitted near the same point, and which causes a more intimate mixture of the gases, and by its presence assists the chemical changes. These changes are somewhat complicated, but we will endeavour to give some idea of them. It has been already stated that sulphurous acid is capable of taking up more oxygen directly from moist air; but this action is extremely slow. It takes oxygen, however, rapidly from *nitric acid* (nitrogen + 5 oxygen), reducing it to the state of *nitric oxide* (nitrogen + 2 oxygen), a gas which, by mere exposure to the air, takes up an additional supply of oxygen, generally two equivalents, so as to form *nitrous acid* (nitrogen + 4 oxygen). Now, it is remarkable, that the sulphurous acid readily takes an additional supply of oxygen from this nitrous compound, provided moisture be present. Two more equivalents of sulphurous acid thus become converted into sulphuric, and the nitrous compound becomes reconverted into nitric oxide, again fitted to abstract oxygen from the air, and thus to continue the action. Hence a comparatively small quantity of nitre is sufficient to convert a large portion of sulphurous into sulphuric acid; and were it not that the nitric and nitrous gases are driven off with the used air (nitrogen) of the chamber, a small fixed quantity would suffice for a length of time. In some works the valuable nitrous compounds are retained, by making the waste gas of the chamber pass through a stream of sulphuric acid, which absorbs the nitrous compounds; and this is afterwards separated and returned into the chamber.

The following section will convey an idea of the interior of the chamber, and of the chemical actions which are carried on within it. The boiler which supplies the chamber with steam is shown at B. The sulphur is burnt on the flat hearth of the oven A, which at first has a small fire under it, but this is allowed to go out when the sulphur is fairly ignited. Nitrate of potash or of soda is mixed with sulphuric acid in an iron pot supported on a tripod. The heat of the burning sulphur disengages the nitric acid, which, accompanied by the sulphurous acid, enters the chamber by the pipe *p*, shown in the figure, and meeting with the steam from the pipe *t*, the formation of sulphuric acid commences as already described. In some works the chamber is divided into three or four compartments, by means of curtains of sheet lead proceeding alternately from the top nearly to the bottom, and from the bottom nearly to the top. These curtains are supposed to detain the vapours, and cause them to advance gradually through the chamber, so that the sulphuric acid is almost completely deposited before the vapours reach the discharge tube *g*, which communicates with a tall chimney, or with the apparatus for separating the nitrous acid gas from the waste gas of the chamber. *

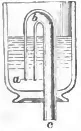


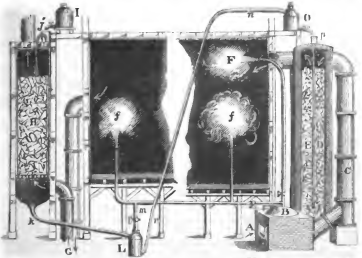
---

* The following figure will give an idea of the principle on which this separation is effected in the French works, in some of which

The chamber may be worked day and night without intermission, or only for a certain number of hours. In the one case, provision must be made for supplying the chamber with a continuous current of

not more than 3 lbs. of nitre are found necessary to convert 100 lbs. of sulphur into 300 of acid. The gases pass through a succession of large chambers, on leaving the last of which they descend into a refrigerator immersed in a tank of water at G, from whence they ascend into one or more tall cylindrical chambers (such as H), which are filled with coke loosely piled, and resting on a grating below, so that the gas has to filter through all its interstices before escaping into the atmosphere. This coke is kept continually wet with concentrated sulphuric acid, supplied from the reservoir I. To wet the whole of the coke of course requires a sudden gush of liquid, which must be renewed at certain regular intervals. This is effected by allowing the *constant* stream from I to flow through a little apparatus at J, which is represented at large in the adjoining figure. It resembles the toy called Tantalus' cup, having a syphon *a b c* inserted through its bottom, so that in filling it, no liquid will run out till it rises above the bend at *b*, when the whole will flow out (being raised over the bend by atmospheric pressure), till reduced to the level *a*. This intermittent flow of acid then trickling down through the coke H absorbs nearly all the nitrous compounds from the escaping gas of the chambers, leaving hardly anything but pure nitrogen (which is useless) to escape. This acid then flows down the pipe *k*, into a recipient L, from whence it can at any time be raised into a reservoir O, by simply



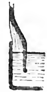


fresh air; since we have seen that the source of oxygen necessary to convert the sulphurous acid into sulphuric acid is the air of the chamber, and not the nitrous acid gases obtained from the nitre, these being merely the media of transfer between the oxygen of the air and the sulphurous acid. In the second case, on what is called the *intermittent plan,* sulphur is burnt for two hours; steam is admitted, and the whole left to settle for an hour and a half: the conversion of the gases into acid then goes on for three hours, during which time the drops of strong acid are heard rattling like hail stones on the bottom of the chamber. The chamber is then opened for three-quarters of an hour, to admit fresh air and prepare for another charge.

In a chamber of the capacity of 27,000 cubic feet, nine hundred weight of sulphur are burnt in twenty-four hours. The state of the interior of the chamber is ascertained by openings in the roof, each covered with a glass bell. When the interior of the glass does not appear thickly covered with drops, the

admitting high-pressure steam from the pipe *m* into L, thus pressing the acid up the pipe *n* into its destination. Now from thence it is again made to flow (through another Tantalus' cup *p*) into other columns of coke similar to H, such as D, E; and the fresh sulphurous acid gas, immediately as it comes from the furnace A, is made to pass through these coke columns (sometimes three or four times up and down) before entering the first chamber. The effect of this is to *denitrify* the acid which is trickling down through the coke; and its nitrous compounds, being separated, act on the sulphurous acid and air in the manner already described, so that a considerable quantity of the sulphurous acid is here oxydized, and much more sulphuric acid is drawn from the foot of these columns than entered them from the reservoir O. Thus not only is there a great saving of nitre, but also of the chamber room required for making a certain quantity of acid, because the first portions of it are made in the columns D, E. A saving of *all* the fuel required for supplying steam to the chambers is also effected by using for this purpose the heat evolved by the combustion of the sulphur, which is burnt in the furnace A, under the boiler B, and is found to generate just the necessary quantity of steam. The French, however, do not decompose the nitre in this furnace, but use nitric acid in the liquid form, introduced into one of the chambers; and this leads to a complex arrangement which need not here be detailed.

proportion of steam is increased. A sample of the product may be tried, and the depth of the acid liquid at the bottom of the chamber ascertained, by a simple contrivance. An opening is made in the side near the bottom of the chamber by pushing the lead inwards, and prolonging it so as to dip beneath the surface of the liquid and prevent the escape of gas. The temperature of the chamber ought to be maintained at 130° or 140° Fahrenheit. If below 100°, the formation of sulphuric acid is liable to be suspended, and a white crystalline compound forms on the sides of the chamber. This has occurred in some works during winter, and is called by the French the *maladie des chambres.**



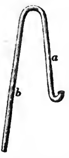
But supposing all goes on well, the acid continues to be formed and to trickle down the sides of the chamber to the bottom, gradually increasing in density. When the specific gravity of the acid varies from 1.350 to 1.450 † it is drawn off from the bottom of the chamber by a leaden pipe into large leaden boilers, where, by the action of heat, a portion of the water of the acid is driven off, the strength of the acid left in the boiler being thereby greatly increased.

These boilers are made out of large thick rectangular leaden plates, by folding up the edges so as to form pans of the depth of ten or twelve inches. Each boiler rests on a close grating of strong iron bars, and has a separate fire. As the acid in the top boiler becomes stronger by the evaporation of the water, it is transferred by means of a syphon tube to the middle boiler, and thence to the lowest. When the acid has acquired the density of 1.650, or 1.700, it must be removed from the leaden vessels, because, at a little over this strength the acid corrodes lead. In order to raise it to the commercial strength it must be concentrated in glass or platinum retorts, for which purpose it is removed from the boilers into coolers, or run through a long worm pipe surrounded by cold water. When glass retorts are used, they are arranged in a long gallery furnace in a double row, each retort being placed in a sand-bath supported by fire-tiles and furnished with a separate fire. The vapour given off usually contains some acid, especially when the concentration is nearly complete, and this vapour is conducted into the chamber or into the leaden boilers. In Messrs. Squarey's sulphuric acid works near Salisbury, lately visited by the writer, the glass retorts are each of the capacity of four or five gallons, with the necks fitting on separately like the top of an alembic. The retorts were arranged in a double row of sixteen, and while in operation the parts of the retort projecting from the sand-bath were covered with a hood of tin plate. From twelve to sixteen hours are required for the concentration: this being completed, the fires are extinguished and the retorts left to cool; after which the acid is drawn off into large brown earthenware vessels by means of a syphon of lead pipe recurved at the shorter arm *a*. This syphon is first inverted and filled with water; then closing the long end *b* with the finger, the short limb is inserted into the body of the retort. On removing the finger, the water in the syphon is set in motion, bringing after it the acid. The water is caught in a small cup

---

* It is thought, however, by the French chemists, that this crystalline substance must always be formed and afterwards decomposed to yield the sulphuric acid. It is formed by the union of two equivalents of sulphurous acid (2 sulphur + 4 oxygen) with 1 eq. nitrous acid (nitrogen + 4 oxygen); but it separates into two equivalents of sulphuric acid (2 sulphur + 6 oxygen), and one of nitric oxide (n + 20), whence it is called a *sulphate of nitric oxide.*

† In estimating density, or specific gravity, water is taken as the standard, or = 1.000. Thus a bottle containing exactly 1000 grains of pure water of a certain temperature would contain from 1,350 to 1,450 grains of sulphuric acid as it leaves the chamber, and about 1,840 grains when finally concentrated for the market. Hence the commercial specific gravity of sulphuric acid is said to be 1.840.



Digitized by Google

held under the end of the syphon; this flows out with a gurgling sound, and the moment it ceases the cup is removed and the acid appears: it falls down into the deep jar in a full, smooth, quiet stream, very much resembling oil, and reminding one of the origin of the old name of *oil of vitriol*, applied to it from this circumstance. The acid is next transferred into large globular green glass bottles, called *carboys*, securely packed with straw in wicker baskets. Each carboy holds from 80 to 100 pounds weight of the acid; the necks are closed with glass or earthen stopples, luted on with clay or loam, and tied over with coarse canvass. In this way it is sent into the market.

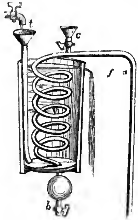
In the above works the glass retorts are found to answer very well. They generally require to be renewed about once a-year: no retort is ever disturbed in its sand-bath while it remains entire; but when, from exposure to draught or to too much heat, a retort is cracked, it is removed at once, unless the crack is situated in the upper part, where it admits of patching with white lead.

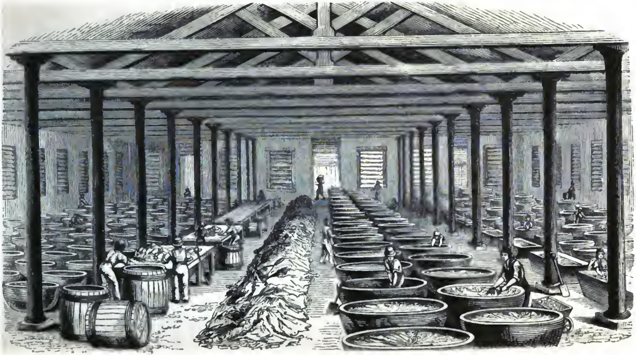
In large acid works, where the quantities produced require the incessant working of the apparatus, this system of *glass-retorting* is not practicable. The danger and great loss arising from breakage induced the late Mr. Samuel Parkes to introduce stills of platinum, a metal which resists the action of sulphuric acid even at high temperatures. These stills are made of thin sheets of platinum soldered together with pure gold:[*] they are oval in shape, and of various sizes, and are preserved from the direct action of the fire by being set in cast-iron jackets, arranged over the flue of a furnace. The stills have platinum heads and beaks like common stills, and the beaks are inserted into leaden worms, in which the watery, sulphurous, and nitrous acid vapours given off during the concentration are condensed and conveyed to the water on the floor of the chamber.

---

[*] These stills are nearly all made in Paris, and are of the capacity of from 5 to 20 cwt.; they cost from 1,700*l.* to 2,600*l.* each; and although one of these retorts wears out in two or three years, yet it is found more economical in large works to use these costly vessels than the cheap and abundant material, glass.

When the acid is sufficiently concentrated in the platinum retorts, they are in some cases lifted off the fire, together with their iron jackets, and let down into a cistern of cold water. The boiling hot acid is in this way speedily cooled; but this contrivance is very clumsy and dangerous, and has been superseded in many works by an ingenious syphon made of platinum twisted into a worm, and contained in a vessel of cold water. The acid is cooled in passing through this worm, thereby rendering it unnecessary to disturb the retort. In order to fill this syphon, the shorter leg *a* is plunged to nearly the bottom of the still; the stop-cock *b* to the longer leg, or worm, is closed; the worm is filled with cold acid through the funnel *c*. The stopcock to this funnel is then closed, and that at *b* suddenly opened; a quantity of acid then flows out sufficient to rarefy the small portion of air in the upper part of the pipe *a*, and cause the hot acid to rise over the bend, and thus produce a continuous stream. The flow of the acid can be regulated by opening the stop-cock *b* more or less, and a constant supply of cold water may be kept up in the outer vessel *v* by the pipe *t*, which constantly supplies colder and heavier water to the bottom of the vessel *v*, while the water heated by the worm escapes through the side opening at *f*. The platinum retorts can be charged from four to six times a-day, which gives them a great advantage over glass retorts.





SODA CRYSTALLIZING HOUSE.

THE MANUFACTURE OF SODA.

In the providential arrangements of the world, the absolute necessaries of life are either supplied with unsparing abundance, or may be procured with moderate exertion. Air, light, and water are necessary to our existence, and are supplied without exertion on our part; salt is a necessary ingredient of our food, and is stored up in immense quantities under various forms. Not only do the waters of the ocean contain common salt as their chief saline ingredient,[*] but in countries far removed from the ocean, vast stores of *rock-salt,* or *sal gem,* as it is called, are frequently treasured up in the earth at a moderate depth beneath its surface. In the extensive wastes of great continents, the soil is often covered or impregnated with salt. Salt-lakes and natural brine springs are also not uncommon in some countries; and when these sources appear to be altogether wanting, a supply of brine may be obtained by boring.

When the salt is in solution it can of course be obtained in the solid form by evaporating the water which holds it. Artificial heat is generally too expensive for this purpose, and advantage is taken of the air and the sun acting upon a large shallow surface of salt water contained in ponds lined with

---

[*] Seawater contains on an average about three-and-a-half per cent. of saline matter, of which nearly three per cent. is common salt; the remaining half per cent. consists chiefly of salts of magnesia, which impart to seawater its bitter flavour and clamminess. The composition of seawater varies in different places; thus, the southern ocean contains more salt than the northern; the sea generally contains most salt where it is deepest and most remote from land; its saltness is always diminished in the vicinity of large masses of ice. Small inland seas are in general less salt than the ocean, but the Mediterranean contains rather larger proportions of salt than the ocean.

Digitized by Google

clay, and secured from the influx of the tides. Such are the *salterns* of our own country, and the *salt-gardens* of the south of Europe. At the flow of the tide, seawater to the depth of from two to six feet is allowed to enter a large pond by opening a flood-gate, where it deposits its sand and mud. The clear water is conveyed by pipes and open channels to a series of level ponds, divided into numerous compartments. By the time it has arrived at the hindermost pool, the salt begins to separate, and to cover the surface with a saline incrustation. This is collected by means of rakes into small heaps at the side of the pond, and left for the mother liquor* to drain off. When no more salt separates by crystallization, the remaining liquor is allowed to flow off into the sea. The small heaps of salt are collected into larger heaps, and left for some time under a covering of straw; this protects them from the rain, while the chloride of magnesium liquefies and drains off by absorbing moisture from the air.†

The salt is separated from the water of brine springs also by the process of evaporation, many curious contrivances being resorted to, to expose a large surface to the action of the air. Very weak brine springs may thus be worked with advantage, since the low price of salt renders it scarcely possible to pay the cost of carriage from place to place, or to afford fuel for evaporating the brine artificially.

Where extensive beds of rock-salt exist, a bore is in some cases made into the bed; fresh water is let down, and pumped up again saturated with salt, which is liberated by evaporation. In other places, rock-salt is obtained by mining. In some cases, it is perfectly clear and colourless; while in others, indeed in most cases, it is coloured red, either from clay, bitumen, or animal infusoria. This generally requires to be purified by dissolving and recrystallizing.

---

* When all the salts that will regularly crystallize have been extracted from a saline solution by evaporation and cooling, the liquid which remains is called the *mother-liquor*, or *mother-water*.

† Many of the salterns on the British coast which were in full operation during the war are now abandoned, the sources of salt in this country being chiefly beds of rock-salt, and salt-springs in Cheshire, Worcestershire, and Staffordshire.

In addition to the immense consumption of salt for culinary purposes, there is an enormous demand for it for the purposes of the chemical manufacturer; this being the source of nearly all the soda and its compounds in common use, and also of the chlorine used in making bleaching powder, &c.

Between the years 1805 and 1823, there was a duty of fifteen shillings per bushel on common salt; consequently its use was limited, as its name *table-salt* implied, almost entirely to the purposes of food. The soda used in soap-making and for other purposes was obtained by burning marine plants, such as the *Salsola soda* and *Salicornia herbacea* on the shores of the Mediterranean and other warm climates; the ash thus obtained was named *barilla:* while on the coasts of Ireland, and the western coasts and islands of Scotland, an inferior article, named *kelp,* was procured by burning the *Fucus vesiculosus* and other species of fuci. Good barilla contains about one-fifth carbonate of soda, the remainder being sulphate of soda, chloride of sodium, and earthy and carbonaceous matters. Kelp contains only from two to seven per cent. of pure carbonate of soda. Nevertheless, as the duties on barilla and common salt were exceedingly high during the late war, the manufacture of kelp flourished in Scotland. The annual rental of the kelp shores of the island of North Uist alone amounted to 7,000*l.* Scotland at one time furnished annually 25,000 tons of kelp, which has been known to sell for 20*l.* a ton; the average price, however, was about ten guineas.

The repeal of the duty on salt almost entirely superseded the manufacture of kelp, the supply of soda being now furnished chiefly by the decomposition of common salt by a process invented by a French chemist, named Leblanc, at the close of the last century. Previous to the revolution of 1789, the soda used in France was obtained from marine plants as above described, chiefly from the coast of Spain. The wars in which France was engaged with nearly all Europe, put a stop to this and other branches of native industry. The importation of potash was also stopped, and all the supplies of that substance that could be obtained in France were devoted to the manufacture of gunpowder. The manufacturers of glass, soap, &c. were thus deprived of an article essential to their very existence. In this emergency the Committee of Public Safety called upon all citizens to place in the hands of commissioners, without any regard to private interests, any plans for the preparation of soda that might be known. The commissioners reported, that among the numerous plans submitted to them, that by Leblanc was most practicable, and best adapted to the wholesale dealings of the manufacturer. This plan was adopted, and the first establishment for carrying it out was erected at St. Denis in 1804. After the repeal of the salt duty, the process was introduced into this country, and altogether it has been in use for nearly half a century with little or no alteration in its most important details.

The chemical name of common salt is *chloride of sodium,* its two constituents being united in the proportion of thirty-five parts by weight of chlorine to twenty-three of the metal sodium. It may be formed artificially by adding muriatic acid* to soda, the hydrogen of the acid uniting with the oxygen of the soda to form water, and the chlorine of the acid with the sodium of the soda to form chloride of sodium. From this method of forming common salt, the term *muriate of soda* was formerly applied to it.

The first part of the process consists in converting common salt into sulphate of soda. This is done in reverberatory or *decomposing furnaces*, as they are called, a number of which are arranged side by side, all discharging their flues into a tall chimney, which is the most conspicuous object on approaching the alkali works from a distance. The floor, or sole of each furnace is usually of brick, but is sometimes lined with lead, and is usually divided into two compartments, in one of which the liquid portion of the mixture is evaporated, and in the other the residuary sulphate is calcined. In some furnaces the evaporation and calcination are carried on in the same division. The figure at p. 33 represents a furnace of the former kind. In the division A, farthest from the fire, called the *decomposing bed*, the salt and sulphuric acid are brought together. The quantity of salt introduced at one charge varies, according to the size of the furnace, from two or three cwt. to half a ton. A nearly equivalent weight of sulphuric acid (not concentrated, but of the same strength as it leaves the chamber,) is poured very slowly on the salt through an opening in the roof, closed at other times with a leaden plug, or through a leaden syphon funnel B, as in the figure. The quantity of acid is so adjusted that the salt may be in excess, which is far more desirable than an excess of acid. The mixture is equalized by stirring with an iron rake covered with sheet lead. Abundant fumes of hydrochloric acid result from the decomposition, which are conveyed through the flue into the chimney, and discharged into the air, or they are condensed into liquid hydrochloric acid; but as the consumption of this acid bears only a small proportion to that of soda, it is generally more profitable for the manufacturer to allow the acid fumes to escape into the air, where, on emerging from the top of the chimney, they form a white cloud of acid, which rains sterility and desolation on the surrounding country. Many alkali works have been indicted as nuisances on this account.

---

* This acid is now more properly called *hydrochloric* acid, the new name indicating the chemical composition, namely, hydrogen and chlorine.

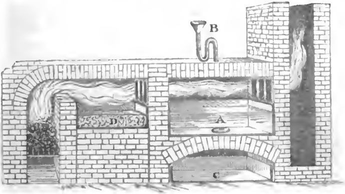
Attempts were made to remedy the evil by discharging the fumes higher in the air, where it was supposed that the great dilution, by combining with atmospheric vapour during their descent, would render them comparatively harmless. This is the origin of those wonderful chimneys, such as that of Muspratt, 495 feet high, and 30½ feet in its lower, and 11 feet in its upper diameter, and containing a million of bricks in its structure,—while the chimney of Tennant's soda works at St. Rollox near Glasgow is of still larger dimensions. These costly structures have not been found to answer the purpose for which they were intended, so that it has been necessary to condense the gas as fast as it is discharged from the mixture of salt and sulphuric acid.* But to return to the decomposing furnace. In about two hours the fumes cease to be copious, and the residuary sulphate of soda becomes a pasty mass. This is now pushed out of the decomposing bed through an opening at the back of the furnace into a kind of vault C, furnished with a chimney, by which means the workmen are not exposed to the suffocating acid fumes. Another charge is then immediately introduced, and the decomposition goes on as before. The product of the first charge having cooled down, so as not to produce acid

---

* Patents have been taken out at various times for contrivances for condensing the acid fumes, and converting them to some useful purpose. In one contrivance, the chimney is filled with rounded flints, and in another with coke, kept constantly wet by a small stream of water from the top; and the acid thus condensed by exposure to an extensive humid surface is conveyed along a pipe at the bottom of the chimney, into a subterranean reservoir. In another arrangement, the condenser consists of a series of upright channels or flues, in which the fumes alternately ascend and descend: water falls into these channels from above, and is distributed over boards placed obliquely. Or by another contrivance water is admitted at the bottom of the condenser in the form of a fountain. In some works the acid fumes from the salt, instead of being condensed, are advantageously employed in the manufacture of bleaching powder (chloride of lime); in other works the condensed acid is employed to generate carbonic acid from limestone, for the manufacture of bicarbonate of soda, or of carbonate of magnesia.

Digitized by Google

fumes, is next shovelled into the other compartment of the furnace nearest the fire, called the *roasting bed* D, where it is exposed to a greatly increased temperature, which in an hour or two dissipates all the remaining muriatic acid. During this operation it changes from yellowish to white. It is now called *salt cake*, and is raked out to make room for another charge.



The object of the next process, which is the most important in the manufacture of soda, is to convert the salt cake or sulphate of soda into carbonate of soda, which is done by heating it to redness, with charcoal and carbonate of lime. By the original method, 100lbs. of salt cake were mixed with the same weight of chalk, and 55 lbs. of charcoal, all ground to a coarse powder, and well mixed by sifting. But as in this country wood-charcoal is too expensive to be used for the purpose, small coal is substituted, and the carbonate of lime may be either in the form of limestone or chalk. The charge, amounting to 2 or 2½ cwt., is heated in a reverberatory furnace, called the *black-ash furnace;* this is oval in shape, and about 10 feet long in the sole, all corners being avoided, in order that no portion of the charge may escape the action of the fire and the stirring rods. The sole is divided into two parts, one of which, the farthest from the fire, is higher than the other part. The first division is the *preparing bed*, in which the charge is first heated, to avoid cooling the furnace. The second division, called the *fluxing bed*, is slightly concave.

The proportions of the salt cake, coal, and carbonate of lime, as well as the weight of the charge, vary at different works. The charge is shovelled in upon the preparing bed, and spread evenly; when sufficiently heated, it is transferred, by means of an iron tool shaped like an oar, to the fluxing bed, which should be at a full red heat. As soon as the mixture is ignited and begins to clot on the surface, it is turned cautiously over by the oar or spreader, so as constantly to expose a fresh surface to the fluxing action of the fire; care being taken not to raise the lighter portions into a dust, or they would be carried away by the draught of the furnace, and wasted. When the whole mass has a doughy consistence, chemical decomposition begins; jets of sulphuretted hydrogen and carbonic oxide, called *candles* by the workmen, escape from various parts of the mass, which is now sedulously worked about with the spreader and an iron rake. At length the mass of soda melts, and from the rapid escape of gas, ap-

SODA FURNACES.

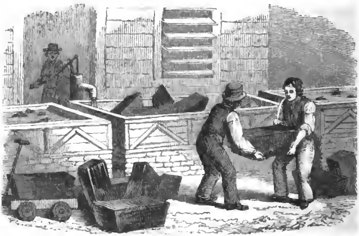
pears to boil. At length it settles down, and when all the "candles" have disappeared, the mass is raked out into cast-iron troughs or iron wheelbarrows, where it becomes solid, and forms a mixture of what is called black-ash, with *ball-soda* or *British barilla.* A second charge is then shifted from the preparing to the fluxing bed, and a third charge immediately placed on the preparing bed. In some large works a ton of the mixture is thus worked off in six hours.

The chemical changes which take place in the above process are somewhat complex, but the most important may be stated thus:—The sulphate of soda, by calcination with the coal, loses its oxygen, and becomes converted into sulphuret of sodium; the carbonate of lime and the sulphuret of sodium then act upon each other, the oxygen of the lime converting the sodium into soda, and the carbonic acid of the lime uniting therewith to form carbonate of soda, while the sulphur of the sodium unites with the calcium of the lime* to form sulphuret of calcium. This last-named substance, called *soda waste,* is a source of great annoyance to the manufacturer; it is bulky, and applicable to no useful purpose yet known. Vast heaps of it accumulate in the neighbourhood of alkali works, often making it necessary to purchase land merely to accommodate it. Attempts have been made to recover the sulphur from it, but hitherto the cost has exceeded the value of the sulphur regained.

The next process is to separate the soluble matters from the black ash. A ball of about 3 cwt. as it leaves the black ash furnace, affords an average of 1¼ cwt. of soda ash. The insoluble ingredients consist of carbonaceous matters, carbonate of lime, and a compound of lime and sulphuret of calcium. The soluble ingredients are carbonate of soda, a little undecomposed sulphate of soda and common salt, some caustic soda, and a few other ingredients. The separation of these matters is the first step towards the preparation of pure soda from black ash, and this is effected by reducing the mass to fragments, either by crushing it under mill-stones, or by exposing it to the vapour of water, which causes it to swell up and fall to pieces. The fragments are put into iron vats, and covered with warm water. In ten or twelve hours the solution is drawn off, and the residue washed six or eight times successively, either with fresh water or with the washings of other vats. The lye thus obtained is evaporated to dryness in leaden pans, by which a carbonate of soda is obtained, mixed with a little caustic soda and sulphuret of sodium. This is further purified by mixing it with about one-fourth of its weight of sawdust or coal-dust, in a reverberating furnace, when the sulphuret of sodium parts with its sulphur and becomes converted into carbonate of soda. In some cases the sawdust or coal is omitted, and the calcination carried on in what is called the *white ash furnace*. When the liquid assumes the consistence of mortar it is raked into a large iron vessel, with a false per-

---

* Lime is an oxide of the metal calcium.



BLACK-ASH VATS.

forated bottom, to allow the mother liquor to drain off from the crystals. The drained mass is then put into a finishing furnace, and moderately calcined, being worked about in all directions, so as to bring every part within the flame and in contact with air. The residue of this operation when ground under millstones is the *white ash* or *soda ash* of commerce, and is sufficiently pure for most of the manufacturing applications of soda; but for the manufacture of plate glass, and for furnishing crystals of carbonate of soda, the ash is rendered still purer by another calcination at a moderate heat. For the crystalline carbonate, the purified ash is dissolved in hot water to saturation, and the solution run into large cast-iron pans. The soda separates in large well-formed crystals, which are broken up, and the mother liquor allowed to drain off. These crystals are carbonate of soda, nearly pure: 100 parts contain 21.81 soda, 15.43 carbonic acid, and 62.76 water; when exposed to air they fall to powder; boiling water dissolves more than an equal weight of them. The mother liquor which drains off contains nearly the whole of the foreign salts, and is evaporated to dryness: the residue generally contains about 30 per cent. of alkali, and serves the purposes of the crown glass and soap manufacturer.

The engraving at page 26 represents the crystallizing house of Messrs. Chance's alkali works at Oldbury; the writer is indebted to these gentlemen for the opportunity of inspecting, on a very large scale, the interesting processes above described.

THE MANUFACTURE OF SOAP.

As the manufacture of sulphuric acid is necessary to the production of soda, so the manufacture of that useful article **Soap** depends in great measure upon an abundant supply of soda. In common language, soap is a compound of certain fatty substances with soda or potash. Its detergent properties depend entirely upon its alkalies, a portion of which combines with the greasy matters intended to be removed by washing, rendering them soluble or miscible with water without corroding. The caustic alkali used alone would act more powerfully as a detergent, but it would corrode organic substances if used freely. In ancient times the soap used appears often to have been simply the alkali more or less caustic,—such, indeed, as is still used in cottages by filtering water through wood ashes. Such appears to have been the soap mentioned in Jer. ii. 22: "Though thou wash thee with *nitre* and take thee much *sope.*" The Hebrew word *borith*, which in this passage has been rendered *sope*, refers to vegetable lye, salt, or potashes. In another passage, however, (Mal. iii. 2,) the *fuller's sope* spoken of is from the Hebrew word *nether*, which is mineral lye, salt, or soda. The first express mention of soap, properly so called, is said to occur in Pliny and Galen. The former declares it to be an invention of the Gauls, though he prefers the German to the Gallic soap. He states that soap was made of tallow and wood ashes; that the best was made of goats' tallow and beech-wood ashes, and that there were two kinds of it, hard and soft.*

The alkali used in making soap requires to be caustic, as no salt of the alkali, not even the carbonate, is well adapted to saponify the oil or fat. The crude alkali sent to the soap works is generally a carbonate; this is mixed in a large iron vat with lime and water;

---

* An interesting historical notice of Soap will be found in Beckmann's *History of Inventions.*

the lime withdraws the carbonic acid from the alkaline carbonate, forming insoluble carbonate of lime or chalk, and leaving the caustic alkali in solution. For common yellow soap, black ash or ball soda is used; by steeping which in warm water, a solution of carbonate of soda is obtained. For white and mottled soaps, this solution is evaporated to dryness and calcined to get rid of any remaining sulphur. For soft soap, potashes are used; these are prepared by digesting wood ashes in water, evaporating to dryness, and calcining the residue in an iron *pot*, whence the name of *pot-ashes* is derived.

The vessels in which the caustic lyes are prepared are circular, about five or six feet in diameter and four or five deep, with a plug near the bottom. Immediately within the plug is a filter of ashes supported on bricks. The vessel is filled with alternate layers of quick lime and black or white ash; and in general three or four such vats are in operation at once,—the first vat being nearly exhausted by previous washings, the second less exhausted than the first, the third less than the second; while the fourth is the newly made vat, not yet wetted. Hot water is made to percolate through the first vessel, and the weak lye thus obtained is sent successively through the other three vats, increasing in strength each time. The residuary mixture in the vats, consisting chiefly of carbonate of lime and a minute quantity of alkali, is disposed of to the glass manufacturer, and is also used as a manure for stiff clay lands.

The other component part of soap, namely the unctuous matters, may be divided into two great classes — *fixed oils* and *fats*. These substances are of first-rate importance to the welfare of a country: the very large amount of carbon contained in them makes them valuable as sources of food and of artificial light; and those fats which are unfit for food can always be turned to profitable account by the soap, candle, and other manufacturers.

Most fats and fixed oils, vegetable as well as animal, are mixtures of two, and generally three distinct compounds, each of which taken singly has all the properties of fats. The first of these substances, called *stearine,* (from *στεαρ,* tallow or suet,) is solid at common temperatures; the second is *oleine,* (from *ελαιον, oleum,* oil,) and is liquid at ordinary temperatures, and even so low as the freezing point of water; the third substance has been called *margarine,* (from *μαργαρον,* a pearl,) on account of its mother-of-pearl lustre; it constitutes the solid fatty ingredient in mutton-tallow, and is solid at ordinary temperatures. All fats, therefore, are mixtures of the fluid oleine with the solid stearine or margarine.* If the solid is in larger proportion than the fluid, as in various kinds of tallow, it requires a greater degree of heat to melt it; if the fluid preponderates, as in the oils, its melting point is lowered.

Each of these three substances contains an organic base, or, in other words, a substance capable of uniting with acids to form (in most cases) a neutral compound like potash, soda, and other metallic oxides. This organic base is named *glycerine* or *oxide of glyceryl,* and is combined with an unctuous substance which has all the characters of an acid. While the glycerine is common to all the three fatty principles, the acid in each has its own peculiar characters.

The acid in *oleine* is called *oleic acid,* which combining with the oxide of glyceryl of the oleine, forms *oleate of glycerine.*

The acid of *stearine* is called *stearic acid,* which in combination with the oxide of glyceryl of the stearine, forms *stearate of glycerine.*

The acid of *margarine* is called *margaric acid,* which combining with the oxide of glyceryl of the margarine, forms *margarate of glycerine.*

These fatty compounds are decomposed by free alkalies, such as potash or soda;* their acids quitting the glycerine to unite therewith, forming a soluble soap; the glycerine remaining behind in the mother liquor. The hard soaps of commerce when made with oils, (palm and cocoa-nut oils excepted,) are chiefly mixtures of oleate and margarate of soda, with little, if any, stearate. When the hard soaps are made with animal fats, they are mixtures of oleate, stearate, and margarate of soda.

---

* Palm, and a few other oils, contain a peculiar fatty principle, which does not fall into the above arrangement.

As in the time of Pliny, soaps are still divided into *hard* and *soft*. The hard are made from fats and vegetable oils, with soda as a base; the soft, from fish oil or vegetable drying oil, with potash as a base. A hard soap may be made with potash if a solid fat be employed; but soda soaps are always harder than potash soaps with the same fatty substance. The stearate of soda, which may be taken as the type of hard soaps, scarcely changes with ten times its weight of water; but the stearate of potash forms therewith a thick paste or viscid solution.

The only unctuous materials employed in the manufacture of soap in this country are tallow, palm oil, cocoa-nut oil, olive oil, oil of grains, (linseed and rapeseed,) whale oil, seal oil, cod oil, hogs lard, kitchen stuff, and bone fat.† Cocoa-nut oil is used in the preparation of marine soap, or such as can be used with sea-water.

Tallow is the concrete fat of oxen, deer, sheep, goats, and other large quadrupeds, separated from the fibrous matter which accompanies it. It consists chiefly of stearine with a little oleine, and soon becomes rancid on exposure to the air. There are two chief varieties of tallow, arranged, according to its purity and consistence, into *candle* and *soap tallow*. It is generally sufficiently pure to be used in soap-making without any previous preparation. The supply is made up by home slaughter, and also by importation, chiefly from Russia, which furnishes us with no less than 60,000 tons annually. A large quantity is also sent by the states of Rio de la Plata. The heterogeneous mixture collected in kitchens and sold to the tallow chandler under the name of *kitchen stuff* is also boiled down for tallow.

---

* The fatty compounds are also decomposed by the earths lime and magnesia, and by metallic oxides, as those of lead and zinc. Lead soap is used in pharmacy, when it is called *plaster;* zinc soap is an ointment. Lime soap, which is insoluble, is formed in the shape of a curdy precipitate, when soluble soap is mixed with hard water; the carbonate or sulphate of lime in the water, and the soap, mutually decompose each other, the oily acids of the soap combine with the lime in the water, and the carbonic or sulphuric acid of the lime unites with the alkali of the soap. No lather can be formed until the whole of the lime is thus taken up.

† In the soap works of Messrs. Hunt, of Lambeth, visited by the writer, kitchen stuff and bone fat are chiefly used as the unctuous materials.

Palm oil is obtained from the western coast of Africa, south of Fernando Po, from the fruit of the oil palm (*Elais guineensis*). The fruit externally is of a golden yellow colour, and about the size and shape of a pigeon's egg. Its fleshy covering is detached from the kernel and bruised into a paste; when this is agitated with boiling water, the oil rises to the surface, and concretes as it becomes cold to the consistence of butter. Fresh palm oil is of an orange yellow colour, of a sweetish taste, and has an odour resembling violets. It melts at 81°, but after it has been kept some time its melting point is 90° or 96°. It becomes rancid by exposure to air, both glycerine and fatty acids being liberated. It contains about two-thirds of its weight of a peculiar white solid fat which has been named *palmitine;* the remainder consists principally of oleine. About 20,000 tons of palm oil are annually imported into this country in exchange for goods of British manufacture; and the cause of humanity requires that this traffic should be encouraged, since it has proved a most important instrument in the reduction of the slave trade, the native Africans being profitably engaged at home in the preparation of the oil, thereby rendering it a matter of interest to retain their services instead of disposing of them to the slave dealer. The present import duty on palm oil is 6*d.* per cwt. It is much cheaper than tallow, and is largely used in making white soap and candles, for which purpose it is first bleached by one of the various methods contrived for the purpose, the most common of which is perhaps either by means of chromic acid, or by exposure to air, light, and moisture, at a temperature of 212°. In making common soaps the unbleached oil is used.

Our limits will not allow us to notice the sources and peculiar properties of the other oils and unctuous matters used in soap-making. The chemical principles are similar, whatever be the fatty or alkaline ingredients of the soap. In this country and in the north of Europe white soap is made from tallow and soda. In France, Italy, and other places where the olive-tree grows, an inferior olive oil is used for the purpose. One ton of soap requires from 10 to 14 cwt. of tallow or olive oil; the proportion of alkali varies in different works; but supposing it to be pure and dry, the proportion required for the saponification of different oils and fats varies from about 10 or 14 soda, and from 15 to 20 potash, for every 100 parts oil or fat. But it is usual to employ an excess of alkali to facilitate the separation of the soap from the mother liquor. In the best Windsor soap the tallow is mixed with about 10 per cent of inferior olive oil, and in white soap a portion of lard is sometimes substituted for an equal portion of tallow, which prevents the soap from being too hard.

The ingredients are mixed in large boilers, or *coppers,* of cast-iron; they are cast in three distinct pieces, and united by cement made with iron rust, sal-ammoniac, and sulphur: the top and middle pieces, called *curbs,* are set in masonry, and heat is applied, either by steam or by a small open fire acting on the lowest part of the copper. All the oil or tallow is introduced at one batch into the copper; but the alkali is added in several distinct portions.*

---

* The quantity of soap made at once is technically called a *boil.*

Digitized by Google

To a ton of tallow in the copper is added from 150 to 200 gallons of soda lye, (specific gravity 1.090,) and the whole is gently boiled. In one or two hours, a viscid emulsion is formed, capable of being drawn out into threads. Common salt is now added, which separates the soap from the lye, thereby causing it to rise to the surface. When the soap is completely separated, the liquid ceases to froth on being boiled. The fire is now withdrawn, and the soap-pan allowed to cool; the spent lye is pumped off, and another quantity added, stronger than before, its specific gravity now being about 1.140. The mixture is boiled for a few hours, until nearly all the free alkali is taken up; the soap is separated from the liquor by the addition of salt, as before; the fire is withdrawn, the mixture cooled, and the spent lye pumped off. These operations are repeated several times, with lyes gradually increasing in strength, until the soap has a slightly alkaline taste, feels dry, and not oily. In this way the soap is boiled two or three times every day for two or three days, until the saponification is complete, and the soap is well washed and purified.

The soap, while still in a pasty state, is removed from the soap-pan in buckets to the frame room, and poured into rectangular *frames*, or *sesses*, as they are called in Liverpool. The interior length and breadth of these frames, as settled by the excise, are forty-five inches long by fifteen inches wide; they are about ten inches deep, and are made smooth, so as to fit closely together; and are piled up, and bound tightly together by means of iron screw-rods, to the height of from five to twelve feet, forming a sort of square well, capable of holding two tons of soap. Within this well the soap is cooled and solidified; but for yellow soap the frames are of cast-iron.

When the soap is solid and cold, the screw-rods are removed, the frames lifted off, and the soap stands as a compact mass, moulded to the interior form of the frames. It is cut by wires into slabs two or three inches thick, and these are subdivided into bars for sale. These bars are piled away crosswise, in the form of a well, interstices being left for the circulation of air. The soap is allowed to remain in this condition for some time, to allow the solution of salt, with which the soap is slightly impregnated, to exude.

Mottled or *marbled soap* is made of the same materials as white soap, but the tallow is selected with less care, kitchen stuff being used as one of its sources. The process of saponification is also similar, the only difference being in the time occupied in the various boilings. The brown veins of mottled soap are referred to minute traces of sulphuret of iron; they are sometimes produced intentionally in the soap, after the boiling with the last service of lye is completed, by sprinkling a small quantity of very strong sulphuretted lye; this, filtering slowly through the soap, produces mottling.

Silicated soap is, properly, a mixture of silicate of soda with hard soap, to the extent of one-fifth; this additional quantity of alkali adding greatly to its detergent properties. It is, however, generally made by mixing with the pasty soap, while in the frames, a quantity of china clay, previously rubbed up with caustic lye. As clay possesses no detergent properties, its addition to soap can only be regarded as an adulterant. It is said that these soaps can be used at sea with salt-water.

Yellow soap differs from white or mottled only by the addition of rosin. This substance is a refuse product in the distillation of turpentine, and is very much cheaper than tallow or oil; consequently, its introduction into soap enables the manufacturer to produce a cheaper article than if tallow or oil were alone used; but as rosin contains no glycerine, it is not capable by itself of forming soap with an alkali. In making yellow soap, palm-oil is now generally substituted for tallow; about 3½ parts of palm-oil being used for every one part of rosin. If the rosin be in larger proportion, (as it often is,) the soap is soft and dark-coloured. The rosin is introduced in coarse powder, with the last charge of lye, when the saponification of the palm-oil is nearly complete. It is well mixed by agitation, and the boiling continued for some hours, lye being occasionally added, to preserve an excess of alkali until the soap is fully formed, when the lye is withdrawn, and weak fresh lyes added, for washing and purifying the soap. The resinous scum which rises to the surface is removed for another operation, and the soap is conveyed to iron frames to solidify. Yellow soap usually contains 1 part soda, from 10 to 11 parts oil and rosin, and from 24 to 50 per cent. of water; the latter quantity, however, is far too much.

Transparent soap. White tallow soap, cut into shreds, and made perfectly dry, is heated in a still, with an equal weight of spirits of wine, with turmeric, or archil. When the spirit is saturated, the heat is withdrawn, and the solution left to settle. It is then poured into tin frames to solidify. It is afterwards exposed to dry air for a few weeks, and cut up into cakes for sale.

Soft soap. Soda or hard soaps, differ from potash or soft soaps, chiefly by the manner in which they combine with water. In the one, the water is chemically combined; in the other, it is merely in a state of mechanical mixture. In this country, soft soap is usually made with whale, seal, olive, and linseed oils, and a certain quantity of tallow, the object of which is, to produce white granulations of stearate of potash, called *figging*, from the resemblance to the granular texture of a fig. These granulations are improperly regarded as proofs of the good quality of the soap, and are on this account sometimes imitated by the addition of starch, or slaked lime.

The lyes used should be caustic, and of different strengths. A portion of the oil being poured into the pan, is heated to the temperature of boiling water, when the weaker lye is introduced. The mixture is then gently boiled, and stronger lye occasionally added, until the saponification is thought to be complete; this is judged of by the boiling becoming less tumultuous, the froth subsiding, and the paste becoming transparent and thick. The process is thought to be complete when the paste ceases to have an acid taste, and when a little, put out on a cool glass plate, assumes the proper consistency. It is then packed in casks for the market. The granulations above spoken of do not usually appear till two or three weeks after the soap has been made, and in warm weather not at all. The general composition of soft soap is—in every 11 or 12 parts, alkali 1 part, fatty acids from 4½ to 5 parts, water and impurities from 5 to 6 parts. The deliquescent nature of this soap renders it impossible to separate it from the lyes, as in the case of hard soaps; hence the saline impurities of the lyes remain in the soap.

Some oils, such as hempseed oil, impart to the soap a greenish colour which is much esteemed. Manufacturers are always skilful in preserving appearances which form the popular test of the goodness of an article, and hence this greenish hue is imparted to soft soap by the addition of a little indigo.

Soft soap is largely used for cleansing woollen yarns and for stuffs, and also in linen bleach-works. Its applications in the laundry are very limited.

The average yearly consumption of soap in Great Britain from the year 1829 to 1832, during which time the duty was 28*l.* per ton, has been estimated at 100,605,850 lbs. In 1833, the duty was reduced to 14*l.* per ton.

From 1834 to 1836, average consumption 118,902,631 lbs.
„ 1837—1840, „ „ 119,542,150 „
„ 1841—1843, „ „ 128,164,991 „

Taking the quantity of soap consumed, and dividing this among the population of Great Britain, the annual allowance to each person would be about 7¼lbs.

Digitized by Google

In the Isle of Man, where soap is free of duty, the annual allowance per head is more than 8½lbs.; and in Jersey, where it is also duty free, the allowance exceeds 13lbs. per head. But in this country, the annual allowance of 7¼lbs. to each person, suggested by a comparison of the consumption of soap with the population, requires some explanation. Agricultural labourers and others, earning 10*s*. per week and under, probably do not consume more than half a pound of soap per week for a family of six persons, which is at the rate of 4 lbs. each per annum. Well paid workmen, and small shopkeepers, probably consume 10 lbs. each; and the middle and upper classes, 15 lbs. each. These calculations are, however, liable to be disturbed by a large illicit trade in soap. Mr. Porter states that there are about fifty persons in England who each take out an annual licence, the charge for which is 4*l*., and who do not pay duty to the excise on a greater quantity than one ton in the course of the year; leaving room for suspicion that the licence is used as a cover for fraudulent processes. There are besides great numbers of persons who make soap secretly, and without taking out any licence, and who consequently pay no duty whatever. It is doubtful whether it can ever be desirable to extract a revenue from soap, the use of which among the people should be encouraged. If the duty were repealed, good soap would be reduced from 4½*d*. and 5*d*. to 3*d*. per lb. There is no soap duty in Ireland, and an allowance is made for the duty on soap used in the silk, woollen, cotton, and linen manufactures; a drawback is also allowed on exports to our own colonies. With this exception, we have scarcely any foreign trade in soap. The excise regulations exclude our soap from most foreign markets, by limiting the manufacturer as to the size of the bars, the specific gravity, the choice of materials, and the mode of manufacture.

R. CLAY, PRINTER, BREAD STREET HILL.

THE USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

COALS AND THE MANUFACTURE OF GAS.

COALS AND THE COLLIERIES.

MAN is not more distinguished from the lower animals by his articulate language than by his knowledge of the use and properties of fire. Most of the lower animals flee before this wonderful element; none seem to comprehend its use; many enjoy its warmth, but none know how to sustain it. Even the apes, which mimic most of the actions of man, never venture to imitate him in kindling and sustaining a fire. They will collect around the fire which the travellers have left, and enjoy its warmth, but they have never been known to add fresh fuel, although it may be lying about them in abundance. But man, even in his savage state, generally knows how to obtain fire, and to control it to his use. The most primitive method of obtaining it is by rubbing two pieces of dry wood together. Mr. Bennet saw at Tahiti the process in common use among the South Sea islanders. A man took a piece of dry puran wood, twelve inches long and two inches thick; with another stick of the same tree, sharpened to a point, and held with both his hands at an angle of about 45°, he rubbed the former gently as it lay on the ground, until he had scratched a groove in it several inches long. Then continuing the same operation, but pressing the point harder upon the lower piece, and increasing the velocity of the motion, some brown dust was soon formed within the groove, and collected at one end. In a few seconds smoke was apparent, and the dust was ignited. The spark was then immediately conveyed into a finger-hole opened in a handful of dry grass. The man blew upon it, and waving the tuft in the air, the grass was quickly in a flame. The whole process did not occupy more than two minutes.*

The most common description of fuel in general use is undoubtedly wood, and next to this, coal. Where these are not to be obtained, various substances are used as fuel. Among eastern nations, the dung of camels and other herbivorous animals is dried and burnt, and even in the midland counties of England, cow-dung is sometimes collected, wetted with water, formed into bricks, and dried in the sun for fuel. In Egypt the mummy pits have for ages afforded abundance of fuel; on the shores of the Caspian sea, naphtha, a natural product, is in common use, and at Baku, one of its ports, there is no other fuel than naphtha and petroleum. In other parts of the world asphaltum springs, and springs of natural gas, furnish materials for cooking and for illumination. The inhabitants of sea-coasts collect sea-weed for fuel; the natives of Ireland obtain peat from their bogs, the spent bark of the tanner furnishes turfs, and the oil of the seal supplies the Esquimaux with both light and heat.

---

* Forests are said to have been set on fire by the rubbing together of the arms of trees during a violent wind, thus accounting for some of the extensive fires in the forests of America. In India, the large bemboos as they are swayed by the wind emit fire from their hard glossy stems through the violence of their friction, and in this way a sea of fire to the extent of several miles has been kindled in the forests of the mountains skirting the Coaduar Ghaut near Calcutta.

In our own country coal is the article most commonly used, and certainly in the wide range of its usefulness it is superior to all the other descriptions of fuel. Whether we regard its use in culinary operations, or as a source of warmth and ventilation to our apartments; whether we consider the enormous supplies of gas furnished by it, or its use in smelting the iron-stone with which it is in some places associated in this country, there is certainly no other description of fuel which can compete with coal. And then how abundant and extensive is the supply, and how conveniently situated for distribution. If our coals had been deposited in the bowels of high mountains, they would have been comparatively useless, for we could not have conveyed them from the mountains in sufficient quantity, nor have resided in such cold sterile situations, far from the convenience of water carriage. The most convenient haunts of the busy, social, and commercial world are in rich and pleasant valleys and low plains near the seas and large rivers, and in such spots as these, coals are found perfectly convenient for home consumption and for distribution by water carriage.

The deposits of coal in our own island are called *coal-fields*, and are generally divided into—1. The great northern district, which includes all the coal-fields north of the Trent. 2. The central district, including Leicester, Warwick, Stafford, and Shropshire. 3. The western district, subdivided into north-western, which includes North Wales, and south-western, which includes South Wales, Gloucester, and Somersetshire.

In these fields the coal is separated into a number of distinct layers or strata of various thicknesses, by means of layers or strata of slaty-clay called *shale*, and coarse hard sandstone called *grit*, forming altogether what are called *coal-measures;* or in other words, beds of sandstone, shale, clay and coal lie one above another, in repeated alternations, to a great depth. The strata of coal, however, technically called *seams*, are very thin compared with the other associated beds. Though extending under large tracts of country, they are often only a few inches thick, and never more than six or eight feet, except one seam in Staffordshire, which is thirty feet, but must rather be regarded as a collection of thinner seams nearly in contact. But the interposed strata of grit and shale often exceed 700 feet in aggregate thickness. Under this series is the mountain limestone,* forming various calcareous strata of variable thickness, sometimes exceeding 900 feet. This limestone rests on a bed of old red sandstone, varying in thickness from 200 to 2,000 feet. The term *coal formation* sometimes includes these two great series of strata, although in general the coal-measures lie above them, the lowest coal-seam commonly resting immediately on the mountain limestone.

The coal obtained from the above-named coal-fields is of various qualities, and its value is generally estimated by the proportion of bitumen contained in it. There are three principal species:—1. The *caking coal*, known also by many other provincial names, which is most commonly found in the Northumberland and Durham mines: it contains about 40 per cent. of bitumen. 2. The *cannel* coal, as it is called in Lancashire, and *parrot* coal in Scotland, where it is also found: this contains about twenty per cent. of bitumen. 3. *Stone* coal, also known under many other names, contains little or no bitumen: this is the ordinary coal of the Staffordshire and Scotch collieries.

---

* So called because its outcrop usually protrudes beyond that of the strata on either side of it, so as to form ridges. See A, fig. 1. A similar character belongs, in a minor degree, to several other calcareous strata, especially the chalk; and it is from this fact that the collections of strata resting immediately on the mountain limestone, and also those overlying the chalk, have so universally obtained the name of *basins*. As the London clay, for instance, forms a valley bounded on all sides by ridges of chalk, so the coal strata are chiefly disposed in basins surrounded wholly or partially by ridges of mountain limestone.

The first description of coal, known in London as *Newcastle coal*, is obtained from the great northern coal-field, which supplies not only the metropolis, but a vast circuit of towns and villages on the coast, from Berwick to Plymouth, and we may add, a considerable portion of the continent. Proceeding northward, we enter the southern extremity of this coal-field, a little beyond the Tees, at a place called Staindrop; passing over it, nearly in the middle, we pass through Durham, Chester-le-street, Newcastle, Morpeth, and reach the opposite margin at Warkworth, on the river Coquet, a distance of nearly sixty miles. Passing over an interval of about three miles, we again meet the coal, and travel over it through Alnwick and Belford towards Berwick, a distance of 25 miles, making in the whole an extent of coal-field of about 80 miles in one direction. From Berwick-on-Tweed to the estuary of the Tyne below South Shields, the coal extends along the coast line, and even dips below the German Ocean. The figure of this immense coal-field is very irregular, but the extent in a cross direction would be nearly passed over by taking the line of the Roman wall which commences near North Shields, and proceeding westerly to Brampton near Carlisle. The whole area of this district, including the coal formations, lying under what is called at Newcastle, "the west country," as well as the more important measures surrounding that town, cannot be under 1500 square miles.

The various deposits which form the coal-measures do not occur in regular horizontal unbroken planes, as might be supposed. There is no doubt that when first deposited they were in this condition, but at various times this horizontal position has been disturbed by some upheaving force from below, whereby the coal-measures have in many districts been made

Digitized by Google

to assume the shape of a huge trough or basin, rising on all sides from a central point, the sides of the basin being composed of sandstone or limestone, and the middle filled up by strata superior to the coal-measures, viz. magnesian limestone and new red sandstone. Shafts have in some cases been begun in the latter, and sunk through the entire thickness of the former, in order to arrive at the coal. This will be better understood by referring to the accompanying diagram, (fig. 1) which represents a section across a coal field such as would result from making a deep perpendicular cut in the ground, and removing all the strata on one side; we should then see a wall exposed like a vertical cliff on the seashore.

Now it must naturally follow from the arrangement of these *coal basins*, as they are sometimes called, that the edge or boundary line of each stratum must appear at the surface somewhat like the concentric layers of an onion cut in two. This "coming to the day," or appearance of the coal at the surface of the ground, is called the *basset* or *outcrop*, and serves to determine the outer form or side of the basin. Coal-basins are generally elliptical, sometimes nearly circular, but often very eccentric, being much greater in length than in breadth.* In many cases one side of the basin upon the narrow diameter inclines more, or has a much greater *dip* than the other, whereby the trough or lower part of the basin is thrown much nearer to one side than the other. From this description it must be clear that in a perfect basin all the strata regularly crop out and meet the surface in every point of its boundary. But few coal-fields, however, are thus circumscribed on every side by the outcropping of older strata. The two great fields of Northumberland and South Wales are bounded (the former on the east, and the latter on the south) by

---

* The great South Welsh coal-field, comprising an area of upwards of 900 square miles, is in the form of a long-necked flask.

FIG. 1.—SECTION OF THE GENERAL FEATURES OF COAL FIELDS.

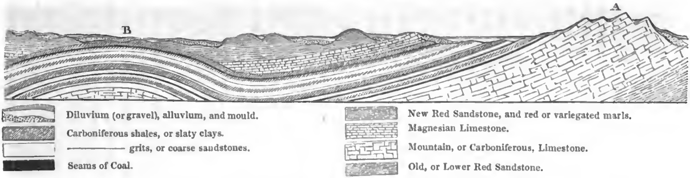
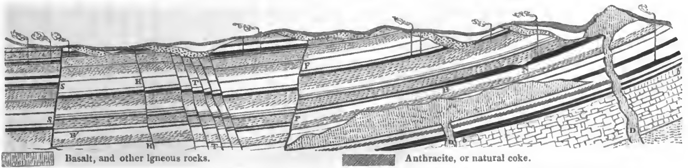

A
B
Diluvium (or gravel), alluvium, and mould.
Carboniferous shales, or slaty clays.
——— grits, or coarse sandstones.
Seams of Coal.
New Red Sandstone, and red or variegated marls.
Magnesian Limestone.
Mountain, or Carboniferous, Limestone.
Old, or Lower Red Sandstone.

FIG. 2.—ENLARGED SECTION OF THE ACCIDENTAL FEATURES OF COAL FIELDS.


S
S
H
H
B'
T
T
F
F
N
B
D
D
b
b
Basalt, and other igneous rocks.
Anthracite, or natural coke.

D D, Whin Dykes. F F, S S, Faults, or Slip Dykes. T T, Troubles. H, Hitch, or Step. *b* and B B', Bands. N, Nip, or Baulk.

the sea, so as to be strictly only half-basins, and the Leicester and Warwickshire field has none of the characters of a basin, being surrounded on all sides by overlying strata, under which the coal-measures dip lower and lower, till they are at too great a depth to be profitably worked. Thus they have no outcrop, and their extent is unknown, reaching, in all probability, under the surrounding new red sandstone into the Lancashire and other fields. Such a field is represented to the left of fig. 1, at B.

The internal upheaving force (whatever it may have been) which converted the horizontal strata into basin-shaped arrangements, most probably at the same time produced certain fissures or fractures, often nearly vertical, and stretching through the whole mass, (see fig. 2). These rents are of the utmost importance to the miner, and may be beneficial to him or not, according to circumstances. They are called *dykes* because they divide the seams or bands of coal into fields, and are *up-throw* or *down-throw* dykes, according as the edge of the strata appears to an observer to be higher or lower in regard to his own position. They are also called *shifts*, as the miners consider they have shifted the strata on their sides; but the most common name is *faults* or *troubles*, from their troubling or putting to fault the pitmen.

Some of these dislocations of strata are so considerable as to obtain a place in geological maps. In the coal-field of Northumberland and Durham, the most remarkable is called the *Main* or *Great Dyke* or *Ninety-Fathom Dyke*. The last term originates in the fact that the beds on the north-side are ninety fathoms lower than those on the south side of this dyke. In some places its width is not great, but in Montague Colliery it is twenty-two yards wide, and is filled with hard and soft sandstone.* From the south side of this dyke two others branch off, one to the south-east, twenty yards broad; and the other to the south-west, which is called from its breadth the *Seventy-Yard Dyke.* It is filled with sandstone, and intersects the upper seam of coal, which however does not appear to be thrown out of its level by the interruption. A slip dyke of such small amount as not to disturb the continuity of the workable seams (the slip being less than their thickness), as at H, fig. 2, is called a *Hitch.*

---

* Other dykes, technically called *whin dykes*, contain basalt and toadstone, and other rocks, of igneous origin. Such dykes may or may not be *slip dykes*, i. e. cause a shifting of level in the adjacent beds. Thus, those represented in fig. 2, at D D, are not accom-

As may be supposed from an inspection of the diagram, dykes are a frequent source of difficulty and expense, by throwing the seams out of their levels, and filling the mines with water and inflammable gas, whereby many fatal accidents arise. On the other hand, dykes and faults have their advantages; for when they are filled, as is often the case, with stiff clay, numerous springs are dammed up and brought to the surface, instead of pouring into the mine. By means, also, of these dykes, valuable beds of coal are preserved within the field, which would otherwise have cropped out and been lost. Thus, the general depression between the faults F F and T T in fig. 2, brings in two thick seams, which would not otherwise occur in this part of the field, as they belong to a higher level. Several valuable beds of coal near the main dyke would not have been available but for the general depression of the beds occasioned by that chasm.

panied by any slip. In approaching within a few yards of these once molten streams, the operation of fire is evident in the conversion of loose grits into compact quartz, and of clay or shale into slate and porcelain jasper, while the coal-seams are diminished in thickness, and completely charred or converted into blind-coal, anthracite, cinders, sooty ashes, or in some cases coke, as perfect as that obtained from gas retorts. When basaltic or other igneous dykes reach the surface (or what *was* the surface at the time of their protrusion) their matter is either heaped up so as to form a hill, (as happens with the right hand dyke, in fig. 2,) or spread out into undulating masses, (as occurs with the other dyke, fig. 2,) or sometimes into extensive strata, destroying a vast extent of coal, or converting it into anthracite, as in the Ayrshire field.

Among other accidents of coal fields, we may also mention *bands—i.e.,* thin strata of grit or shale occurring in the heart of a coal seam, and, from a scarcely perceptible origin, (as at *b* and B, fig. 2,) gradually thickening, till, at a distance of perhaps many miles, they entirely usurp the place of the coal, or reduce a thick and valuable seam to thin useless ones, (as at B′.) Another very different phenomenon is that of *nips—i.e.*, sudden and merely local thinnings of the seam by an excrescence from the roof or floor, as at N; this, however, is very rare.

Let us now briefly notice the method of obtaining the coal as adopted in the great Northern Coal-field.

The probable existence of valuable beds of coal, and perhaps the beds themselves, may be discovered by the operation of *boring;* which consists in drilling a hole perpendicularly in the ground, making it pass through all the strata in succession, and examining the fragments from time to time as they are brought up. The boring tool is a kind of gimlet or chisel, attached to an iron rod by means of a screw, and worked by machinery at the surface. It does its work by chopping or scooping, according to the hardness of the rock. As the depth increases, successive lengths of rod are screwed on, while the fragments of rock are taken out with an auger.

The information furnished by the borer determines the next operation, which is to sink a perpendicular shaft from the surface, so as to pass through the various strata containing the coal, and as many of the beds of coal as may be worth working. In the north of England the shaft is either cylindrical or elliptical in form, and from ten to fifteen feet in diameter. To prevent the loose strata from falling or being washed in, the upper portion of the shaft is bricked or walled, and where the ground is weak this casing is continued down to the solid rock. It seldom happens that any great depth can be reached without liberating springs of water, which sometimes pour into the workings in such torrents that to continue the excavation seems like madness. It is, however, continued with success by a judicious system of casing or *tubbing;* that is, the shaft is lined with three-inch boards, fastened to a circular wooden framework called a *crib*, attached to the side at certain distances. Of late years, metal cribbing has been preferred; and in recent shafts forty fathoms (240 feet) of a pit have been completely lined with a strong casing of cast-iron. While all these works are being carried on, the water, which would otherwise flood the shaft, is drawn to the surface by a powerful steam-engine. The shaft is continued deeper and deeper, until the first workable seam of coal is reached. The depth of a shaft in the Northern Coal-field is rarely less than twenty-five fathoms, (150 feet); it is usually much more, some shafts being 300 fathoms, (1,800 feet); and an expense of upwards of 50,000*l.* has often been incurred before the seam intended to be worked is reached.

But as soon as this desirable object is attained, the sinking of the shaft is discontinued, and a broad straight passage, called a *bord* or *mother-gate*,* is driven from it into the seam of coal in opposite directions. This bord is twelve or fourteen feet broad, and is made of the whole height of the seam, so as to expose the rock above, which is now called the *roof*, and also the stratum below, which forms the floor, or what in mining language is termed the *thill*. It is also necessary to drive a passage, called the *drip-head*, *dip-head*, or *main-level*, which is not usually straight, the object being to preserve throughout its length, not a straight line, but a constant level, so that the water may collect like a gutter along one side of its floor. This gallery, therefore, resembles the *contour lines* marked on some maps; except that its course is straighter, because the curves in the dip of the strata are commonly far more gradual and extensive than those in the form of the present surface. And this gallery, of course, forms the limit of the colliery in the direction of the dip, for it bounds the area drained or *won*, as it is called, by that shaft. From this level gallery numerous others are driven, towards the rise of the strata, till they reach either the out-crop of the seam or the dip-head gallery of an adjoining colliery, which is called the *rise* colliery. The direction of the bords is arranged so as to follow the natural cleavage of the coal which forms their sides, and consequently is not always at right angles with the dip-head. When a bord has been excavated some distance, narrow passages, called *headways*, are driven from it at regular intervals, on both sides, and exactly at right angles, if the natural cleavage of the coal be cubical, as it generally is; and when these have proceeded eight or ten yards, they are made to communicate with other bords, which are opened parallel to the first and on each side of it. In this way the bed of coal is entirely laid open and intersected by broad parallel passages, about eight yards apart, communicating with each other by narrower passages or headways, which cross them at right angles, and also traverse the whole extent of the mine, immense square or rectangular pillars of coal being left standing between the two. In this state a coal mine has been aptly compared to a regularly built town, the bords being the principal streets, the headways the narrower streets which cross them, while the pillars of coal form the masses or blocks of buildings. When the two cleavage planes of the coal, however, are not at right angles, all the blocks are rhomboidal, much labour being saved by following the natural cleavages, which are usually parallel throughout a vast extent of country, and (what is very singular) are independent of the curvatures in the strata. We have endeavoured to represent this curious geological fact in Fig. 1, by drawing the diagonal lines that represent shale everywhere parallel, notwithstanding the contortions of the strata.

---

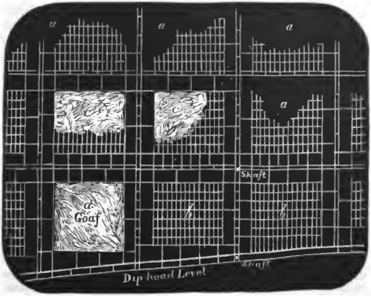
* Principal road. The Saxon meaning of *gate* is *road* or *way*.

The same process is repeated in each seam of a

Digitized by Google

workable thickness which the shaft is deep enough to reach. Seams of only two feet, or even less, are sometimes found worth working; in which case, of course, portions of the roof and thill have to be removed besides the coal, to allow height for the workmen and trams; but it is lamentable to relate, that in the neighbourhood of Bolton, Halifax, and in Scotland, false economy has led to the barbarity of employing boys and women in galleries less than three feet in height. In thin seams, the material taken from the roof and floor serves to build pillars or walls for supporting the superincumbent strata, so that the *whole* of the coal can be extracted. When, however, pillars of coal have to be left, as their contents amount frequently to three-fourths, and never less than one-third, of the whole seam, many modes have been contrived for removing them without

FIG. 3.



danger; the best of which is the mode of working invented by Mr. Buddle.

This method of working the mine is called *pannel work*, the mine being thereby divided into districts or panels, separated from each other by walls of coal forty or fifty yards thick. The coal is extracted from each in succession, beginning usually with the one most distant from the shaft. Large pillars of coal are at first left between the bords to support the roof; the pillars themselves are then removed, the roof being meanwhile supported by stout Scotch fir props; and when all the coal has been extracted, the props are removed and the roof falls in.

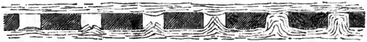
In the annexed figure (3), representing the plan of one story of such a mine, the panels *a a a a* are not entirely laid open by galleries; *b b* are laid open but no pillars yet removed; in *c c* the pillars are being extracted and the roof is falling in, its ruins forming what is called *goaf;* and the pannel *d* is entirely worked out and abandoned.

If all goes on well, and the prospects of the mine appear to be favourable, another shaft is in some cases begun at some distance from the first; and when a communication between them has been effected, one is made *downcast* and the other *upcast*. These terms have reference to the ventilation of the mine, the air being conducted from the downcast shaft through all the bords and workings, which it is made to traverse in succession by means of *stoppings*, or doors, in various places to obstruct its passage and give a proper direction to the current in passing to the upcast shaft. Considerable velocity is imparted to the current, and the ventilation thereby greatly promoted, by keeping a large fire constantly burning in some part of the upcast shaft. The supplies of fresh air passing into a mine must, of course, vary considerably. In the Wallsend Colliery they vary from 2,000 to 3,000, and occasionally 3,800, cubic feet per minute. In some of the large workings, the air has to traverse many miles of gallery before it reaches the upcast shaft, and is frequently twelve hours in doing so, moving at the ordinary rate of two or two-and-a-half feet per second.

Many coal mines are worked without this second shaft, its place being supplied by dividing the single shaft into two distinct portions, by means of an air-tight partition called a *brattice*, one division being downcast and the other upcast. The larger shafts (those fifteen feet in diameter) are divided into three parts, one of which is used for raising the coal to the surface, another for working the pumps for the drainage of the mine, and a third for ventilation, bringing up the air that has passed through the workings.

While the first seam is being worked, the shaft may be sunk to a second or third seam, where similar operations are commenced. Small underground pits, called *staples*, are sunk at intervals from the workings on the upper seam to those on the seam below, for promoting ventilation. In this way an extensive colliery is formed; but the regularity and uniformity of the workings are greatly disturbed by faults and local accidents. If the roof be of hard sandstone, and the floor of soft clay, the pressure downwards will tend to displace and force up the floor; this is called a *creep*. If, on the contrary, the roof be soft, it will sink in and form what is called a *crush;* and if both roof and floor are moderately hard and tough, they will in time meet midway. Fig. 4 shows the gradual progress of a creep, by which not only are the passages eventually filled up, but the coal of the pillars cracked and rendered useless. By the method of panel-working any creep occurring in one panel is prevented by the thick

FIG. 4.



surrounding walls from spreading into the adjoining panels.

The pitmen who excavate the coal are called *hewers.* They begin by cutting a narrow fissure in the lower portion of the coal next the thill or floor of the mine; they then cut deep vertical grooves on each side of the mass intended to be brought away, so as to define its size. The mass is then broken down by means of wedges, or by the force of gunpowder. The latter method is usually adopted in the deep northern mines. A hole about a yard deep is drilled near the roof or top of the working, and the cartridges of gunpowder, called the *shot,* inserted. In some cases two or three shots are inserted; the holes are filled up with coal-dust, and the fuse fired. By this means from sixty to eighty or one hundred tons of coal may be brought down at once. The coal is put into baskets called *corves,* and drawn along the tram-road by lads called *putters* as far as the principal galleries or headways, where it is received into wagons called *rolleys,* several of which being fastened together, are drawn by a horse to the bottom of the shaft, and thence raised by the steam-engine to the surface. The coal is then passed over gratings or screens, to separate the small pulverized coal from the larger masses. These screens are generally formed of bars of iron, half-an-inch apart, mounted in a frame-work, with a convenient slope, so as to allow the coals to slide down easily into the wagons below. The small coal which passes through the screen bars is either delivered in wagons for immediate sale, or accumulated in heaps, or hoisted up and re-screened into *rough*, *small*, and *dust*, by screens with the bars set closer together than in the first.*

---

* The small coal, which was formerly burnt to waste at the mouth of the pit, is now profitably employed in making coke for locomotive engines, iron works, breweries, &c. at home, and for general consumption abroad. It is a curious fact that in some collieries the large coal is actually crushed into small, for the purpose of meeting the extensive and still increasing demands of the coke consumers.

The collier is exposed to numerous accidents in his gloomy workshop, arising from foul air, the falling in of the roof, and the bursting in of water; but these are not peculiar to coal mines. There is, however, one terrible source of danger which distinguishes coal mines, and especially those of the great Northern Coal-field; namely, the escape from the coal itself, in large quantities, of an inflammable gas, called carburetted hydrogen, and, by the colliers, *fire-damp*, which, mingling with the atmosphere of the mine in certain proportions, forms an explosive mixture capable of being ignited on coming in contact with the flame of a candle. The Newcastle coal contains a large quantity of this inflammable gas. which it gives off readily by exposure to heat, and also from the great pressure of the superincumbent strata of the mine. This gas is very much lighter than common air, mixes readily with it, and when poured out into the workings, moves along with the current of air in the direction of the upcast shaft. The quantity of gas poured out into the workings is very considerable, but subject to great variation, some seams being more *fiery*, that is, more full of gas than others; and in working these fiery seams, it is not uncommon for a jet of inflammable air to issue from every hole made for the gunpowder in blasting. But in addition to this constant and steady supply, there is danger of sudden discharges from pent-up reservoirs, such as a fissure or hollow cavity suddenly laid open by the pick. The gas issues therefrom with considerable noise, and forms what is called a *blower*. Blowers may proceed from the roof or from the floor, and are sometimes so constant that the gas is collected, and conveyed by a tube into the upcast shaft, continuing for months or years to pour out several hundred, and even thousand hogsheads of fire-damp per minute. When thus provided for, the blowers are not necessarily a source of danger; and under ordinary circumstances, the ventilation of the mine gets rid of most of the gas that is liberated. But when, from "pricking a blower," or some other cause, torrents of gas are set free, and an explosive mixture formed, the mine is, as it were, converted into an enormous piece of artillery, with an explosive gas in the place of gunpowder, and human beings, horses, and machinery, for solid projectiles. When this terrible engine is fired, which it may be by the approach of a naked flame, the effects, as may be supposed, are most disastrous. Nor is the force of the explosion alone to be dreaded; the fire-damp being exploded, is immediately succeeded by what is emphatically called the *choke-damp*, that is, the oxygen of the air is by the explosion partly converted into carbonic acid, which is fatal to animal life.

In addition to good ventilation the necessity was long felt of being able to traverse dangerous parts of the workings without the liability to explosion from the flame of a lamp or candle. A light of some kind of course is necessary, for the darkness of these deep workings is such that a dark night is almost brightness in comparison. Early in the last century the *steel mill* was invented for the purpose of supplying light without danger of explosion. By this contrivance a stream of sparks is produced from the rapid revolution of a rim of steel against flint. It is doubtful, however, whether this contrivance afforded any real security. Other contrivances followed, but it was not until the year 1812, when the terrible explosion at Felling colliery occurred on the 25th of May, whereby seventy-two persons lost their lives, and a second explosion on the 19th of September killed twenty-three persons, that attempts were made on any thing like a large scale to prevent these fearful accidents. A society was formed at Bishop Wearmouth "for preventing accidents in coal mines." Persons were invited to submit plans for lighting the mines without danger; whereupon numerous schemes were sent in from all quarters, scarcely any one of

Digitized by Google

which, however, was of any practical value.* The committee continued its operations for about two years, when it occurred to Dr. Gray, the chairman, to invite the attention of Sir Humphry Davy to the subject. No sooner was this done than the illustrious chemist accepted the invitation, visited the collieries, and entered with his accustomed ardour upon the inquiry; the result of which was, the discovery of many remarkable properties of flame, and the invention of the safety lamp. Davy found that the proportion of fire-damp necessary to be mixed with atmospheric air in order to render it explosible is about one-fourteenth part. With this admixture there is danger, and the danger increases as more fire-damp is added, until the mixture is most explosible when the proportion varies from one-ninth to one-eighth. By increasing the proportion of the fire-damp the risk of explosion diminishes, and with as much as one-fourth of the noxious gas, the mixture will burn, but not explode. Davy also found that no mixture of fire-damp with common air could be made to explode in tubes of less diameter than about one-eighth of an inch, and that explosive mixtures required a much stronger heat for their explosion than was afforded by charcoal or iron at a red heat. The length of the tubes in which the mixture refused to explode was found to be of no consequence; by continually reducing this length it was found that common wire-gauze (which may be regarded as a collection of tubes whose length is the thickness of the wire) was sufficient; so that by surrounding the flame of a lamp with gauze, the meshes of which are sufficiently small, the flame would not pass through the meshes to fire the

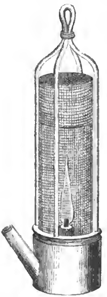
---

* Of these inventions ought to be mentioned the "safe lamps" of Dr. Murray and Mr. Brandling, in which the flame was fed by air introduced through a long flexible tube reaching to the floor of the mine, upon the false assumption that the fire-damp occupies only the higher parts of the mine. Dr. Clanny invented a "steam safety-lamp," into which the air of the mine passed in a current through a tube, and mixing with steam before it reached the light, burned steadily in the wick of the lamp alone.

Digitized by Google

explosive mixture on the outside. See fig. 5. It was

FIG. 5.



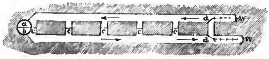
found that the fire-damp burned within the gauze casing, and even made it red-hot, but did not cause an explosion. Of course it was never intended that the lamp should be used in any part of the mine when the fire-damp is so prevalent as to make the wire-gauze red-hot, nor even when the fire-damp causes the flame to flicker and burn blue; the men ought under such circumstances to quit the place until by ventilation the air is made safe. The chief fault of *the Davy* (as the men call this lamp) arises from the small quantity of light which it affords; to increase its brilliancy the men are in the habit of removing the gauze—their only safeguard; or the wire-gauze gets broken and injured; or by moving the lamp swiftly through an explosive atmosphere, the flame is driven against the meshes.* From these and other causes the Davy lamp has disappointed the expectations of those most interested in its use. Accidents are even more common than before its introduction, and experienced men now look for safety rather to improved methods of ventilation than to contrivances for lighting the mines.

It is not safe for the men to be ever more than a few yards in advance of the course of the current; and hence, even at the commencement of working a seam, it is necessary to divide the ascending and descending currents in the shaft, as at *a b*, (fig. 6,) and to begin with *two* parallel bords, connected at intervals by cross passages, which are successively stopped up by wooden partitions, *c c c*, leaving no communication except through the one last opened

---

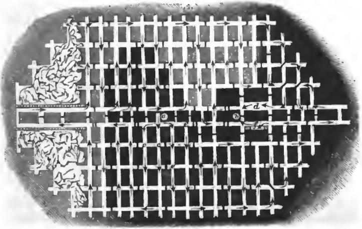
* A compound of hydrogen and sulphur (sulphuretted hydrogen), which takes fire at a much lower temperature than fire-damp, has lately been discovered in coal mines, and may have led to many accidents otherwise inexplicable.

Fig. 6.



or farthest from the shaft; and not only so, but temporary partitions have to be placed at *d d* to oblige the current to circulate quite up to the workmen at w w. When the works are more advanced, the direction of the current through every part by *stoppings* or partitions becomes a matter of no small complexity, as will be seen by the following plan, (fig. 7.)

Fig. 7.



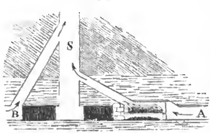
where the arrows represent the course of the air from the downcast shaft *a*, through all the galleries, to the upcast shaft *b*. It will be observed that in most places the current is allowed to divide itself between the parallel bords, which is called *double coursing;* and its advantage is, that if any part of the mine is more *fiery* or dangerous than the rest, the current can there be confined to one course, and thus have

Digitized by Google

its velocity doubled; while in the parts containing least gas, the same current can be allowed to expand into three passages, which is called *treble coursing.*[*]

As the foul air from the more fiery parts must not come into contact with the fire at the bottom of the upcast shaft, (by which the whole current is set in motion,) it is usual to divide the air as it enters the mine, (from the shaft *a*,) into two distinct currents, one of which proceeds through the passages *e e* into the safest parts of the mine only, while the other, *c c*, circulates through the fiery parts, (represented by the lighter shade,) including the goaves, or old abandoned workings, which are always the most dangerous receptacles of gas. The purer current alone is allowed to pass through the furnace *f*, before entering the upcast shaft *b*. The other current is conducted through *d*, and enters the shaft at a higher level, by a tunnel cut obliquely through the roof of the seam, as in fig. 8, where S represents the upcast shaft, B the impure current, and A the purer current feeding the furnace, which, when thus constructed, is called a *dumb furnace.*

Fig. 8.

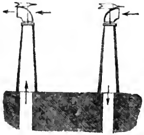


Instead of the draught of a furnace, steam power has sometimes been applied to ventilate the mine by means of air-pumps, or blowing machines. The power of the wind can also be taken advantage of, to assist, in a slight degree, the ventilation, by building over the inlet and outlet two towers or chimneys, with large cowls turned by vanes, as in fig. 9, so that one may always present its mouth and the other its back to the wind.

---

[*] The *double* stoppings in fig. 7 represent those in which doors of communication are required. These are made in *pairs* in order that a person may pass through them, as a barge through a canal lock, without allowing the main bodies of air to communicate. To ensure this, they are sometimes made even treble, and a boy placed in charge of each pair, or set of three, to take care that they are never all opened at once.

FIG. 9.

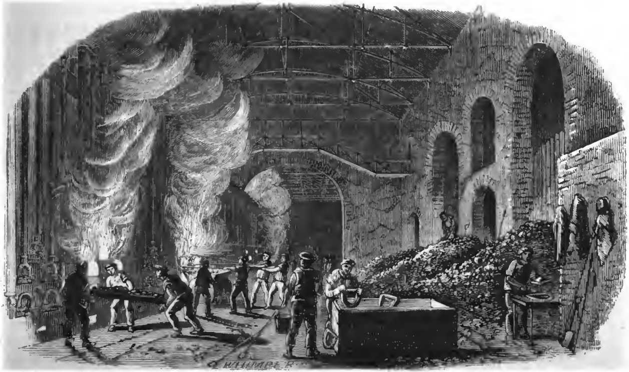


This slight sketch of a colliery and of the collier's occupation may be appropriately concluded by an extract from the report of the South Shields committee:—

"Pit coal is produced by a severity of labour and risk of personal safety to the miner which the workman of no other occupation is exposed to. The pitman descends 200, 300, and sometimes more than 500 yards into the bowels of the earth, and there traverses subterranean passages, frequently for two or three miles in extent, to his work; where, by the glimmering of a small candle, or more imperfect lamp, in a space seldom six feet high, and oftener three or four, he labours in a stooping posture, sometimes lying on his side for eight or ten hours together, in an impure atmosphere, to extract the mineral that aboveground is diffusing light, heat, riches, and enjoyment.

"In such a situation, often without a moment's warning, he is overtaken by destruction. The gases generated in such abundance in the mine, from some accident suddenly explode, and fill the pit with death. In an instant, and in the most fearful manner, he is scorched and shrivelled to a blackened mass, or is literally shattered to pieces against the rugged sides of the mine; or, if out of the immediate range of this terrible piece of ordnance, in a few seconds the *after-damp* spreads itself in every direction, and poisons beyond recovery all that it may reach. Humanity has too frequently to deplore these fearful accidents."

Digitized by Google



THE RETORT HOUSE, AT THE WESTMINSTER GAS-WORKS.

THE

MANUFACTURE OF GAS.

In some parts of the world nature has supplied on a grand scale an inflammable air capable of affording light and heat. Thus, at Baku on the shores of the Caspian sea, the "holy fires," as they are called, are produced by the combustion of a gas which issues from the earth. The burning fountain of Dauphiné is of similar origin; and in Italy, especially in the neighbourhood of the Apennines, similar phenomena occur; as also in the Cordilleras, in Hungary, Greece, England, and elsewhere. The first persons who appear to have turned these natural gasometers to profitable use are the practical Chinese. When the borers for salt water pierce beds of coal, the inflammable gas which escapes is conveyed in pipes to the salt-works, where it is used for boiling and evaporating the salt; other tubes convey supplies of gas for lighting streets, large apartments, and kitchens; and when all these purposes have been served, any excess is got rid of by burning it in a chimney beyond the limits of the salt-works. The Americans of the United States make use of the natural source of gas at Fredonia on Lake Erie, by collecting it in gasometers and using it for lighting the streets of New York.

Although it was long known that the gas in question originated in beds of coal, or in the gradual decomposition of organic matter, it is remarkable that no attempts were made to produce the gas on a large scale artificially, for the purpose of lighting streets and houses, until a comparatively recent period. In the history of this, as well as in that of other great discoveries and inventions, we see the minds of scientific men tending every now and then to a certain object which, if fully carried out, would confer upon mankind a positive benefit. In some cases the scientific minds of the cultivators of natural knowledge are not accompanied by practical habits; so that although a discovery may be scientifically complete, it is far from being practically useful. Then again, practical men, as they are called, may not have enough science to appreciate the discovery of the scientific man, so that for want of knowledge their practical skill may in some instances be of no avail. Such appears to have been the case with gas lighting. So long ago as 1659, Thomas Shirley attributed the exhalations from the burning well of Wigan in Lancashire, to the subjacent coal-beds; and soon after Dr. Clayton (afterwards Bishop of Cork and Ossory) then rector of Crofton at Wakefield in Yorkshire, actually prepared gas by the distillation of coal. In a letter to the Royal Society, dated 12th May, 1688, he speaks of some "sulphureous spirits," which he had drawn from coals, and which he could condense although they were inflammable; "nay, would burn after they passed through water, and that seemingly fiercer, if they were not overpowered therewith. I have kept of this spirit a considerable time in bladders; and though it appeared as if they were only blown with air, yet if I let it forth and fired it with a match or candle, it would continue burning until all was spent." In a subsequent letter, Dr. Clayton describes the distillation of coal in glass retorts, and enters minutely into the products of the distillation.

About the year 1770, a spontaneous evolution of gas took place at a colliery near Whitehaven, which took fire at the approach of a lighted candle, and gave a flame more than two yards long. This was noticed in the "Philosophical Transactions" for 1773, about which time Dr. Hales and also Dr. Watson obtained gas by the distillation of coal. In 1786, Lord Dundonald erected coke furnaces and burned the gases in tubes for the amusement of his friends; but apparently without any other object. A few years after this, (1792) Mr. Murdock, engineer to Messrs. Boulton and Watt, employed coal-gas for lighting his house and offices at Redruth in Cornwall. By the year 1802, the method of producing the gas was so far perfected, that on the occasion of a general illumination, Mr. Murdock lighted up part of the Soho manufactory near Birmingham with a display of gas-lights. But the first application of this light on a large scale was in 1804 and 1805, when Mr. Murdock fitted up the extensive cotton-mills of Messrs. Philips and Lee at Manchester, by which a quantity of light was distributed over the building equal to nearly 3,000 candles. This plan of lighting now began to be general. Mr. Winsor went about giving public lectures on the subject, and thus gradually overcame the ridicule and incredulity which met his plan of lighting a whole city with gas. In 1812 a part of London was illuminated in this way, and in 1815 the method was introduced into Paris. Many improvements in the construction of the apparatus, and in the practical details of the process, were made by Mr. Samuel Clegg, who began to devote his attention to the subject in 1804.

From such small beginnings the system has extended to its present enormous supply. A few years ago it was calculated that the annual consumption of gas in London and the environs amounted to not less than three thousand millions of cubic feet, and the light produced by the combustion may be considered as equal to that which would be obtained from one hundred and sixty millions of pounds of

Digitized by Google

tallow-candles. At the present time the metropolis is lighted by twelve incorporated and one unincorporated gas companies, the united investment of which amounts to about 3,500,000*l.* These thirteen companies are proprietors of twenty-two establishments for manufacturing gas, in which the annual consumption of coal is 350,000 tons. Above nine hundred tons per day are consumed in foggy weather in winter.

The quantity of gas made and distributed, or lost by leakage, in the year 1848, was 3,200,000,000 cubic feet. The amount received during the same period for the sale of gas was upwards of 700,000*l.* The price charged to the private consumer was 6*s.* and for the street lamps 3*s.* 10*d.* per 1000 feet.

From 1827 to 1839, the quantity of gas consumed in the metropolis doubled what it had been from 1822 to 1827; and from 1837 to 1848 it again doubled what it was in the preceding ten years.

The inflammable gas of coal mines and that obtained naturally from the earth is known to chemists as the *light carburetted hydrogen;* that is, a gaseous compound of carbon or charcoal and hydrogen, 100 parts by weight, containing 75 carbon and 25 hydrogen. The illuminating power of this gas is by no means equal to that of another compound of hydrogen and carbon known under the name of *bicarburetted hydrogen*, or *olefiant gas*, and containing twice as much carbon as the light carburetted hydrogen in the same bulk. Olefiant gas does not occur naturally: it is obtained by the destructive distillation of oil, and is also a product mixed with light carburetted hydrogen and other substances more or less luminous, when coal, resin, tar, asphaltum, fat, animal refuse, and other similar inflammable substances, are distilled for the purpose of obtaining illuminating gas.

The best kind of coal for producing good gas in large quantity is cannel coal; next to this, Scotch parrot coal. Where cannel coal is not to be had, a highly caking coal is used. It is estimated roughly, that 100 cubic feet of coal yield from 18,700 to 9,200 cubic feet of gas, according as the best kinds of Scotch or Lancashire coal are used, or the worst kinds of Staffordshire coal.

The coal or other substance used for producing gas, is distilled in tubes of cast-iron, called *retorts;* and usually about seven feet long and one foot in diameter. Before being used they are tested to see that they are free from flaw, by placing them in water and then forcing air into them. If any flaw exist the air escapes in bubbles. Each retort is usually in two pieces, connected by flanges and screws, namely, the *neck* or *mouth-piece*, and the *body*, or hinder part, which, by constant exposure to the fire, soon wears out, and requires renewal, whereas the mouth-piece is scarcely acted on. The retort is charged and discharged at the mouth, which is closed by a lid, and fixed by means of a screw W, and a hold-fast V: it is made air-tight by applying clay or the refuse lime from the purifier between the two inclined surfaces. The gases which are generated from the coal escape from the retort by a wide tube cast into the mouth-piece. This is shown in Fig. 11, which is a more modern method of closing the mouths of the retorts during distillation.

Fig. 10.

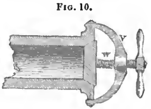
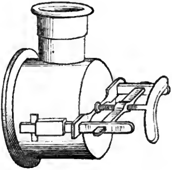


Fig. 11.



The best form of retort for distilling the coal in the shortest time was long a matter of discussion. The

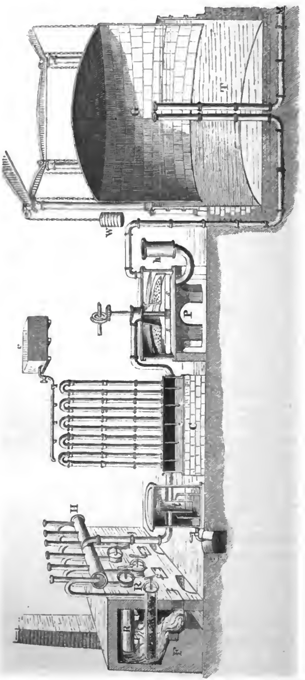
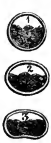


Fig. 12.

first retorts were in the form of a circular tube, No. 1;* these were superseded by the elliptical form, No. 2; and these were further improved by bending in the lower surface, as in No. 3; † the advantage hereby gained being to bring a much larger portion of the charge into contact with the red-hot sides. In all three forms, with the same length of six-and-a-half feet exposed to the fire, 150lbs. of coal only half filling the retort, will cover in the round form a red-hot surface of ten inches in width: in the oval form a surface of nearly twelve inches, while the charge is much nearer the top of the retort than in the circular form. This variation in form has reduced the time required for heating one-half.‡ D-shaped retorts are also in common use.

FIG. 13.



Five retorts are usually arranged in one furnace, two and two, and one above. When there are only three, they are arranged as in Fig. 12, at FR. There are two separate fires to each furnace; and the brick-work is so arranged as to divide and distribute the flame among the retorts. § The tubes, which rise from the retorts, bend down and dip into a large horizontal tube H, called the *hydraulic main*.

---

[*] Circular retorts are still preferred at some works where cannel coal only is employed.

[†] This form is called *kidney-shaped*. Its breadth is now usually from twenty to twenty-two inches; its height in the middle, from nine to twelve inches.

[‡] The average quantity of gas obtained from a ton of Newcastle coal in the kidney-shaped or elliptical retort is 9,000 cubic feet; whereas, in the circular retort of the same dimensions, and worked with the same coal in a similar manner, only 6,400 feet have been obtained.

[§] In extensive gas-works there are from 400 to 600 retorts, of which from 200 to 300 are worked on the average of summer and winter, each retort being charged with about 120 lbs. of coal every six hours. The retort furnaces are arranged in rows generally on each side of the retort house, the flues from the different furnaces meeting in a central chimney. The retorts are generally heated by coke. Two men attend to three furnaces of five retorts each; but as the retorts are kept constantly at work, there are relays of men for night-work.

These arrangements being understood, let us now inquire into the products of the distillation of coal. Supposing the retorts to be at a bright red heat, and just charged, the first action of the heat is to drive off atmospheric air from the retorts, and vapour of water from the coals. As the coal heats, a considerable quantity of tar distils over into the hydraulic main, with a portion of gas consisting chiefly of hydrogen and ammonia. The quantity of gas continually increases, tar and ammoniacal liquor pour over, together with sulphurous acid from the pyrites of the coal. The retorts being kept at a bright cherry-red heat, the gases are most abundantly disengaged; but after a time they cease altogether. It has been computed, that, in an eight hours' distillation, with a uniform fire and the retorts at a constant red-heat, the relative quantities of gas given off are, on a per centage of the whole charge, in the first hour 20, in the second 15, in the third 14, in the fourth nearly 13, in the fifth 12, in the sixth 10, in the seventh 9, and in the eighth about 8. But at these different periods the qualities of the gaseous products are very different. The gas which comes off before the retorts have acquired their proper temperature burns with a feeble light; the best gas is given off when the retort has just acquired a vivid red-heat, for it then consists chiefly of carburetted hydrogen and olefiant gas, there being in every 100 measures of gaseous products from good coal, 82.5 of carburetted hydrogen, 13 of olefiant gas, 3.2 of carbonic oxide, and 1.3 of nitrogen. By continuing the distillation the valuable gases diminish in quantity; and those which burn with little or no light, such as hydrogen, sulphuretted hydrogen, and carbonic oxide, and those which do not burn at all, but extinguish flame, such as nitrogen and carbonic acid, increase in proportion.

From various chemical analyses of the gaseous products at different periods of the distillation, the present method of obtaining good gas from coals has

Digitized by Google

been founded. "They show," says Dr. Ure, "that the distillation should commence with a retort previously heated to a cherry-red, since thereby good gas is immediately produced, and a portion of the tar is also converted into gas, instead of being simply distilled over into the condenser pit; that this heat should be steadily continued during the whole operation from five to eight hours; that it should not be increased, especially towards the end, for fear of generating carbonic oxide and hydrogen gases, as well as of injuring the retort when the cooling agency of gasefication has become feeble; and that the operation should be stopped some time before gas ceases to come over, lest gases with feeble illuminating power should impoverish the contents of the gasometer. Upon the average a pound of good coal affords four cubic feet of gas, or a chaldron of 26 cwt., London measure, affords from 12,000 to 15,000 cubic feet, according to the form of the retort and the manner of firing it."[*]

Now supposing the charge of coal to have been shovelled into the glowing hot retorts, and the lids secured, distillation immediately begins. The tubes which convey the products of distillation from the retorts

---

[*] The following is a recent calculation of the produce of a ton of coals:—

1 ton of coals = 2,240 lbs.

yields,—

1	chaldron of coke[1]	=	1,494 lbs.
12	gallons of tar	=	135 „
10	gallons of ammoniacal liquor	=	100 „
9,500	cubic feet of gas[2]	=	291 „
	Loss	=	220 „
			2,240 „

---

[1] The coal in the process of distillation increases in bulk about 28 per cent. About 25 per cent. of the coke is used as fuel for heating the retorts, and the remainder is sold.

[2] 1 cubic foot of coal gas weighs 214½ grains.

terminate, as already stated, in the hydraulic main, H, which contains a considerable portion of tar, the result of previous distillations; this tar covers the mouths of the conducting tubes, (see Fig. 12,) by which means the retorts are kept perfectly separate and distinct from each other, so that one may be opened and charged without interfering with the rest. Most of the tar which distils over is collected in the hydraulic main, the excess of which is carried away into a tar-cistern *t*, by means of a syphon tube bent so as to leave the main half full of tar;* but by turning a cock at the other end of the main all the tar can be drawn off. When the distillation is complete the lid of each retort is unscrewed, and before it is taken off the gas is ignited at the mouth of the retort:

---

* In the tar cistern the tar occupies the lower position, the ammoniacal liquor, or gas water, floating over it. The latter is used to satisfy a large portion of the commercial demand for sal-ammoniac and carbonate of ammonia. A ton of good coals produces rather more than 200 lbs. of ammoniacal liquor: it is sold at about 6*d.* per butt of 108 gallons. The tar averages about 8 per cent. of the coal: it is used in the manufacture of patent fuel, and of creosote, and as a paint for palings, &c.; and in some gas works it is used as a fuel for heating the retorts. By distillation, 100 lbs. of tar yield about 26 lbs. of an oily liquid known as *coal oil;* the light product which first distils over is *coal naphtha.* Pitch remains behind, and this is used largely for paying wooden piles, &c., and the bottoms of ships. It is cheaper than the pitch of wood tar, but not of so good a quality. Coal naphtha is used extensively for dissolving caoutchouc, and also for burning in the naphtha lamp. By impregnating coal-gas with its vapour, the illuminating power of the gas is greatly increased. It was originally proposed by Mr. Lowe to fill the ordinary wet gas-meter at the house of the consumer with purified naphtha, which was kept filled to the same height from a reservoir in connexion with it, and thus the gas was measured and saturated with naphtha at the same time. The mode by which this object is at present attained, is by passing the gas through an ornamental vase, containing a sponge saturated with naphtha. This vase may be situated any where between the meter and the burner.

But among the secondary products of this manufacture, by far the most important is coke. On an average about two bushels of coke are obtained from a hundred-weight of coals, or about 66 per cent. of the original weight of coal. It is always considerably lighter than the coal, its increase in bulk being about 28 per cent. It is largely used in metallurgic works, as it produces by combustion a higher temperature than any other fuel.

when this has burnt out, the lid is removed, and the glowing coke is raked out into iron wheelbarrows, and into an iron carriage called a *coke-omnibus,* a man every now and then dashing cold water upon it, to quench the burning and to lessen the heat.

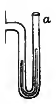
The retorts in each bed are in this way carefully cleaned out by means of hoes or scrapers with very long handles; the retorts can now be seen, throughout their whole length, glowing at a cherry-red heat. Before they are recharged, a man passes a long auger up the pipe leading into the hydraulic main, to clear away any condensed tar, which, if allowed to remain, would prevent the distillation from going on. The retorts are recharged by means of a long curved tray of sheet-iron, called a *scoop*. This is filled with coal, and pushed to the end of the retort, inverted so as to turn out the coal, and then withdrawn. A portion of the coal is immediately converted into gas, which pours out at the mouth in a copious flame; but a man now advances with the cover, previously luted, which he quickly screws on, and the distillation proceeds as before. This discharging and re-charging of the retorts is a very hot and laborious duty, and has a remarkably picturesque effect, especially during the quiet of a clear calm night; the glowing heat of the furnaces, the bursting flames of gas when the retorts are opened, the rush of black smoke and flame which accompanies the fresh charge, the workmen with their long rakes and shovels, the shadows of their naked bodies appearing dark-green upon a red ground; the striking effects of light and shade; the noise, the exertion, the turmoil, the suffocating heat and odour alike oppressive, — all this is in striking contrast with the refreshing coolness and calmness of the sky which is seen through the openings of the gas-house. The effect is perhaps equally striking, although in another way, on a bright day, when the beams of sunshine escaping into the gloomy retort house through chinks in the roof, are so loaded with smoke, and steam, and dust, as actually to appear like solid masses of matter. When the retorts are charged, and the fresh coke has been wheeled away to the heap, the noise, the dazzling bursts of flame, and much of the heat, subside into a more quiet and sober scene, but still the heat and the loaded atmosphere of the place are oppressive, and the writer has always felt more relief in quitting a gas-house than any other factory which it has been his pleasant duty and privilege to visit in preparing these treatises for the press.

Although much of the tar and ammonia of the coal is deposited in the hydraulic main, and overflows thence down the same tube with the gas, into the vessel *t*, yet the hot gas in leaving the main contains a considerable portion of the vapour of these substances, which must be got rid of before the gas can be further purified, otherwise it would condense in distant parts of the apparatus, and stop up the pipes. The hot gas is therefore made to pass from the hydraulic main to the *coolers* or *condensers*, which are variously shaped at different works. A common form consists of a number of upright tubes, surrounded or encased in larger ones containing water, which is kept cold by constantly flowing in at the bottom, and, being heated by the tubes through which the hot gas is circulating, escapes in a stream at the top. This, however, is not so common as the form represented in Fig. 12, called an *air*-condenser, in which the enclosing tubes of water are dispensed with, but the cooling is assisted by cold water trickling down over all the tubes, from the cistern *c*. In this case, however, a greater amount of cooling surface is required, to obtain which there are often twenty or thirty lofty tubes. The gas passes through all these, and, meeting with the cold surfaces of the tubes, the tar is condensed into a liquid form, and trickles down into the divisions of the iron chest at C, whence it flows back into *t*, and can be drawn off from time to time by the tap into a pit or sunk cistern. The gas enters the condenser at the temperature of about 120°, and leaves it at about 60°.

The gas, as generated in the retorts, forces a passage for itself by its own elasticity into the condenser, &c.; but this method is objectionable, because, if a retort should be cracked, or be badly secured, much of the gas would escape and be lost, or if any of the pipes become choked with tar, as they are apt to be, the increasing elasticity of the gas might lead to dangerous explosions. To avoid such inconveniences, Mr. Evans, of the Westminster Gas Works, has introduced a pumping apparatus, called an *exhauster*, between the condenser and the lime purifiers. The effect of this is to relieve the retorts from internal pressure, causing the gas to move through the condensers, and propelling it forward to the lime purifiers.

The actual pressure of the gas as it leaves the exhauster is ascertained by a simple gauge formed of a bent graduated glass tube, containing water or mercury, open at one end, and with the other end screwed into the vessel containing the gas. Thus, if the end *b* of the tube be screwed into a vessel containing gas of the same pressure as the external air, the liquid will be of the same height in the two limbs of the gauge. If the pressure of the gas be greater than that of the external air, the liquid will rise in the tube *a*, and the pressure of the gas will be one, two, or more inches, according to the height to which the liquid rises. If, on the contrary, the pressure of the gas be less than that of the outer air, the atmospheric pressure always acting at the open end, *a*, of the tube, will prevail, and the liquid will rise in the limb *b*. This simple and useful gauge is connected with all the apparatus

FIG. 14.

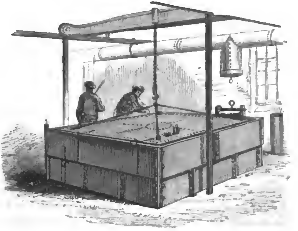


through which the gas passes after leaving the exhauster, or in which the gas is stored.

We have traced the gas as far as the condensers. It still contains a number of useless or injurious gases, some of which must be got rid of, or the consumer would be exposed to injury as regards both health and property. The free hydrogen and carbonic oxide cannot be got rid of; but this is of little consequence, as they are not injurious, but only tend to dilute the gas. The other gases, which are injurious when burnt, consist of sulphuretted hydrogen, and of ammonia, combined with carbonic, muriatic, sulphuric, and sulphurous acids. These are removed more or less completely by means of lime. The gas on leaving the condenser passes into a sort of inverted funnel contained in the upper part of the purifier P, Fig. 12, a vessel full of lime and water, or *milk of lime*, as it is called. The gas on entering, depresses the lime-water in the funnel, and then escapes through numerous minute apertures into the liquid, where the bubbles are dashed about and brought into intimate contact with the particles of lime by means of a stirrer, *ss*, revolving rapidly round by wheel and pinion work. The lime purifier can be charged and discharged by means of a tap; and as the lime-milk becomes saturated with the impurities of the gas, it is replenished from the cistern head *h*. The quantity of lime employed in this operation ought to depend upon the quantity of sulphuretted hydrogen and carbonic acid contained in the gas. If, for example, there be 5 per cent. of these gases, about a pound and a half of lime will be required for every hundred cubic feet of gas. The size of the purifier is made to depend upon the quantity of gas produced from each charge of the retorts, and the lime is changed every time the retorts are charged. In some cases, however, three purifiers are used in succession; these are placed at different elevations, the last being the highest. From this the lime-water overflows into the second, and from the second into the first, which is at a still lower elevation. By this contrivance the gas is brought into contact with lime of gradually increasing purity, and is thereby more thoroughly purified. The spent lime, which is of an excessively fetid odour, is very properly prohibited by law from being thrown out as refuse; it is therefore evaporated in the ash-pit of the furnaces, and the dried lime used as mortar for luting the retorts, &c.; a portion is also sold for mortar or for manure.

Within the last few years, *dry lime*, or more properly *hydrate of lime*, has been substituted for wet lime in the purification of the gas. In the dry lime purifier the gas is introduced at the bottom of a rectangular iron vessel, of any size, and three feet deep, see Fig. 15. This vessel is divided into two compartments by a partition extending not quite to the top. In one of these the gas filters upwards, and then in the other compartment it passes downwards, through several layers of lime, placed on iron gratings or perforated shelves of cast-iron, about

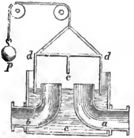
FIG. 15.



seven or eight inches apart. The perforations are three-eighths of an inch in diameter, and three-fourths of an inch distant from centre to centre. The purifier is covered by a light lid of sheet iron. The lime used is fresh slaked, moistened, but not sufficiently so to stick to the fingers; it is placed on each shelf to the depth of about three inches, then wetted with about a gallon of water from a watering pot with a rose. One bushel of quick lime will with proper management suffice to purify 10,000 cubic feet of gas. By being slaked and reduced to a proper consistency for use, its bulk is more than doubled; two bushels of this hydrate will cover a surface of twenty-five square feet two and a half inches deep, which is about the thickness found to answer best. At the Westminster works, a bushel of slaked lime or half a bushel of unslaked lime is allowed for every ton of coals that is distilled. At these works from 50,000 to 74,000 cubic feet of gas per hour are passed through one of the large purifiers, which is twenty feet square.

The gas, after passing through the lime of one purifier, is conducted through a second purifier; then through a third, and even through a fourth. These purifiers are all constructed on the same principle, and are connected by means of a water-valve cock, by which the supply of gas is adjusted and regulated. This contrivance, which is in common use in other parts of gas works for making connexions between pipes, is shown in section in Fig. 16. The upper or floating part, *d d*, is furnished within with a vertical partition *e*, descending from the top about half way down, and only coming in contact with the water in the cistern *c* when it is desired to shut off the supply of gas entirely. This partition is

Fig. 16.



placed between the two pipes *a b*, one of which is the inlet and the other the outlet pipe. Now it will be evident that by diminishing or increasing the weight of the floating part of the small gasometer, or the counterweight *p*, the partition approaches to, or recedes from, the surface of the water in the cistern, and consequently retards or permits the flow of gas from the inlet to the outlet pipe.

The top or cover of each purifier is movable, and fits into a water joint or trough, ten inches deep and six inches broad. The shelves are also movable, so that the upper ones may be removed while the lower are being changed. The spent lime, containing hydro-sulphuret of ammonia, is exceedingly offensive, from the powerful odour which it exhales. This, however, is now entirely removed before the purifiers are emptied, by an ingenious contrivance employed at the Westminster Gas Works. As soon as the top of the purifier is removed, a hollow cylinder, proceeding from the surface of the lime to the bottom of the purifier, is connected by means of a short cylinder with a large horizontal tube (see Fig. 15), which opens directly into the shaft of the chimney of the retort house. The cylinder near the bottom of the lime is perforated with a number of holes, so that while the powerful draught of the chimney rapidly exhausts the air from the horizontal pipe, a current of air is set in motion which filtering through the layers of lime, enters by the holes at the bottom of the cylinder, passes up into the horizontal pipe, and thence to the tall chimney, carrying with it the offensive volatile matters with which the lime is impregnated. The heated air of the chimney speedily effects their decomposition, so that they are thus effectually got rid of, and the lime purifier can be cleaned out without any annoyance to the men or to the neighbourhood. After the lime has been used once, it is burnt in ovens constructed for the purpose, and used a second time. After this it becomes refuse.

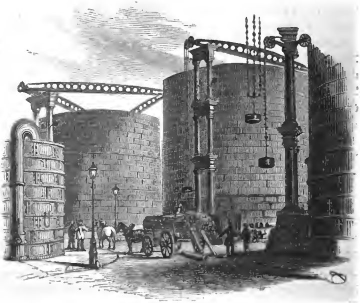
After the gas has been purified by lime it still contains ammonia. The water of the gasometer would absorb this if the gas were kept long enough; it is, however, in most works thought necessary to get rid of it by a distinct process, such as passing the gas through a solution of alum or of protosulphate of iron, (green vitriol,) or through dilute sulphuric acid, or chloride of calcium and other substances. But a water washing is sufficient for the purpose, and at the Westminster Gas Works the gas from the purifier is conducted to the bottom of a tank full of coke, (called a *scrubber,* shown to the left of Fig. 17), for the purpose of increasing the wet surfaces against which the gas plays, and water being introduced at the top, by means of a perforated tube placed horizontally, trickles slowly down over the coke, while the gas passes in the contrary direction.

Supposing the gas to be sufficiently purified by these means, it is passed through a large meter called the *station meter,* which registers the quantity of gas made during any given period, such as an hour, a day, a month, &c.; so that the production of gas at the works can be compared with the quantities registered by the meters of the consumers. At the Westminster Gas Works there are two station meters, both of elegant design, and each inscribed with an appropriate classical motto.

The gas is next conveyed to the *gasometers,* or gas-holders, which form the most conspicuous objects in the gas-yard. These serve the purpose not only of storehouses, but also of communicating to the gas a pressure sufficient to propel it along the pipes, and to cause it to issue in a uniform stream from the jets, so as to burn with a steady flame. The gas-holder is a cylinder, closed at top, and floating or suspended with its open end in a cistern of water. The dimensions of the gas-holder are regulated by the geometrical law, that a cylinder has the greatest capacity with a given surface when its height is equal to half its diameter; hence, the capacity of the gas-holder is such, that when raised to its highest point in the water its height is equal to the radius of the base. It is usual, however, to increase this height by one or two feet, to prevent the possibility of the gas escaping from its under edge when raised to the greatest height in the water. For example, a gas-holder of the capacity of 30,000 cubic feet has a diameter of forty-two feet and a height of twenty-three. This was long considered the largest that could conveniently be made; but the Westminster Gas-works are provided with eighteen large gasometers, of which the largest is ninety-five feet in diameter, forty feet high, and of the capacity of 250,000 cubic feet. The necessity for such abundant stowage will be apparent, when it is considered that at these works a million and a half cubic feet of gas are produced every twenty-four hours during the winter months. These gas-holders are formed of sheet-iron riveted together; after which, several coatings of hot tar are put on on both sides; this makes it gas-tight. If of large size, it is strengthened within with cross iron rods, and the top is supported by rods stretching obliquely down to the sides; the under edge is strengthened by curved cast-iron bars bolted together, to which the oblique rods are attached. A number of rings at the top are connected to the upper ends of the supporting rods; these rings serve to suspend the gas-holder by a chain, which, passing over a pulley attached to a strong outer frame, has a counterpoise weight at the other end, see Fig. 15.

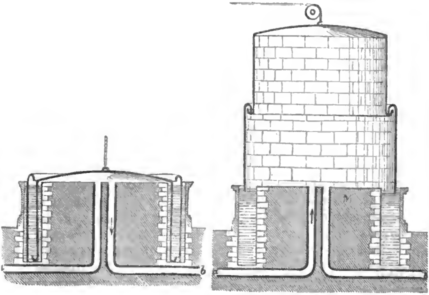
There are several methods of mounting the gas-holders; but the two most common are shewn in Figs. 12 and 14. In the first of these, the gas-holder dips into a tank (T) of water, above the surface of which one pipe opens for the admission of the gas from the lime purifier, and another pipe by which it is conveyed to the main for distribution. With large gasometers this great body of water is an inconvenience, especially in frosty weather, when steam must be introduced to prevent freezing. On this account the arrangement shown in Fig. 18 is preferable. Instead of the great mass of water there is a central core, M, of masonry, brick-work, or sheet-iron, with only a comparatively small ring-shaped space for the water. In the centre of this core are two channels for the two pipes, *a* and *b*, by one of which the gas enters the gas-holder, and by the other escapes into the street mains. The gas-holder, if small, is suspended from its centre by a chain, as before noticed, and to the pillars of the triangular or polygonal cast-iron frame guiding rollers are attached, to keep the cylinder horizontal and enable it to move easily. The evaporation of the water is prevented by a layer of tar upon its surface.

FIG. 17.



By this method of suspension, with the chain and counterpoise, the greater part of the weight of the

Fig. 18.



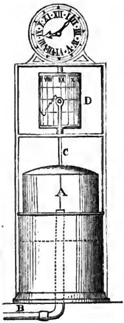
gas-holder is taken off, and only so much left as is necessary to expel the gas. This weight, however, must of course vary in proportion as the gasometer sinks; it must lose a portion of its weight equal to that of the water displaced by the submerged portion; and hence the pressure of the gasometer on the contained gas would vary according to its depth, were it not for an ingenious contrivance: the chain which bears the counterpoise is so adjusted as to equal one-half the weight which the gas-holder loses by immersion. The weight lost by the gas-holder in sinking, is replaced by a portion of the chain coming over the pulley and balancing an equal portion of the chain on the other side, which is the same thing as adding one-half of this portion to the side of the gasometer. Very large gas-holders have also, by a nice adjustment of weight and bulk, been made to require no chains or weights, the buoyancy of the gas, (which is much lighter than air,) serving in all positions instead of a counterweight. This elegant contrivance is not applicable to gas-holders of less than sixty feet diameter. The pressure to which the gas is subjected by the gas-holder is generally such as will sustain a column of from one to two inches of water. (See Fig. 14.)

The great space required for ordinary gasometers, has led to an ingenious contrivance for storing a larger bulk of gas without increasing the area of the ground. Such is the telescope gasometer, shown full and empty in Fig. 18, consisting of two, three, or more concentric cylinders, the bottoms and tops of which, except the uppermost, are furnished with flanges turned in opposite directions, the flange turning outwards and upwards at the bottom, and inwards and downwards at top. The uppermost cylinder is covered at the top, but the others are open both at top and bottom. Now, supposing the cylinders to be all sunk in the cistern, and gas is introduced, the innermost cylinder rises first, and when its bottom reaches nearly to the surface of the water, its curved flange catches the flange of the next cylinder which also rises, and when this has advanced sufficiently high, it lifts the next. The escape of the gas and the admission of air are prevented by the lower flange of each cylinder taking up a quantity of water, which acts as a water lute. These gasometers are usually suspended at three points on their circumference, by means of three chains running over pulleys attached to three pairs of pillars. The larger ones, not telescopic, have commonly eight or twelve such supports, and being decorated in the style of ancient amphitheatres, are often far from unsightly. (See Figs. 12 and 17.)

The gas is distributed to the streets and houses of the town or district intended to be supplied, by means of cast-iron pipes, nine or ten feet long, cast with a turned up margin or shoulder at one end, and a mouth-piece at the other. When placed together, the space between them is filled up with greased tow, and leaded all round, so as to be perfectly air-tight. The smaller pipes for the supply of houses are often drawn leaden or pewter tubes, but ought to be of iron. If a leak in the pewter pipes catch fire, the surrounding metal will melt, and the hole enlarge till the flame becomes dangerous. The supply of gas to the mains is a matter of great importance, not only as regards the convenience of the consumer, but the economy and consequent success of the works. In the dark evenings of winter, the mains must be kept well filled with gas under a certain pressure; when the shops are closed, this pressure must be moderated so as to suit the diminished consumption, and yet be sufficient to keep the street lamps burning; then, again, towards sunrise this pressure must be diminished, and at a certain hour, varying according to the season, cease altogether. Thus it will be seen that the increased pressure from dusk to nine or ten o'clock, and the diminished pressure from that hour till sunrise, is a constantly varying quantity, requiring careful attention on the part of the superintendent.

The very large district supplied with gas by the Westminster Gas Works is divided into a number of sub-districts, each of which consumes a variable quantity of gas, some more and some less. A division containing numerous shops will consume more gas than one consisting chiefly of private houses; so that the pressure for the one requires to be greater than that for the other. The Westminster district has about twenty such divisions (comprising altogether nearly 150 miles of main), and the varying pressures required by each division is managed in the following manner:—In a well-lighted, warm and comfortable room, occupied by a superintendent during all the hours that gas is required to be burnt, is situated a number of small gasometers, called *pressure indicators,* ranged round the room, with the name of the division painted over each which it is intended to supply. Each gasometer, A, Fig. 19, which is about twelve inches in diameter, is made to move in a tank of water in such a manner that it shall rise or fall according to the pressure in the mains, with which it is connected by a small pipe, B. To the upper part of each gasometer is attached a vertical rod, C, carrying a black-lead pencil, which is made to bear upon a cylinder, D, covered with a sheet of paper, ruled so as to mark the twenty-four hours of the day. By connecting the cylinder with a time-piece, it is made to rotate on its axis, by which means the pencil draws a line opposite the hour when it is set going. If the pressure be constant for a number of hours, this line will, of course, be a circle round the cylinder, or a straight line when the paper is unrolled; if the pressure be made to vary, the line will be zigzag. At the end of the twenty-four hours the paper is taken off the cylinder and a new one added, and all these papers are preserved in portfolios, each one for its own division; so that the company has a permanent record of the watchfulness of its superintendent, a mute but truthful referee in case of complaints from customers of insufficient supply, and a clear and distinct index of the gaseous wants of the whole district, or of any one of its divisions to which the company dispenses light.

FIG. 19.

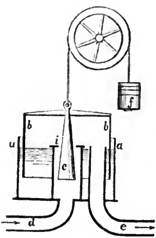


In smaller gas-works, where the district served with gas is not sub-divided, the pressure is regulated by an ingenious contrivance called the *Governor*.

Digitized by Google

This is a self-acting instrument, and regulates the supply exactly according to the demand, which is especially valuable where meters are used. The following section, Fig. 20, will explain the construction of the governor; *a a* is a cast iron tank, containing water, in which the regulating vessel, *b b*, floats: *c* is a cone of cast-iron, suspended by an eye bolt to the top of the floating vessel; *d* is the pipe by which the gas enters, having a plate, *i*, on the top, furnished with an aperture bored to fit the diameter of the cone at the base, and which, if raised to that height, will completely shut off the gas from entering the vessel; *e* is the outlet-pipe, by which the gas escapes to the street mains. By adding or removing the weight of the counterbalance, an increase or decrease of pressure is produced.

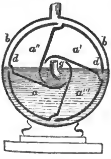
FIG. 20.



The action of the governor is as follows. The outlet pipe is connected with the mains and the inlet pipe with the gasometer supplying gas into the machine; it will be evident that if the density of the gas in the inlet pipe becomes by any means increased, a greater quantity of gas must pass between the sides of the adjusting cone and the aperture in the plate *i*, the consequence of which will be, that the floating vessel will rise, and therefore contract the area of the opening in *i*; and if, on the contrary, the gas in the inlet pipe decreases in density, the vessel will descend: so that whatever density the gas may at any time assume in the gasometers or mains, its pressure in the floating vessel will remain uniform, and consequently the velocity of the gas passing into the mains will be regular; for when the aperture of the plate *i* would admit more gas than necessary for the supply to the mains, the floating vessel rises, and diminishes the area of the inlet pipe, and when, on the contrary, the inlet does not allow a sufficient quantity of gas to come from the gasometers, the gas passes out of the governor into the mains, and in so doing, the vessel descends, and increases the area of the inlet pipe to admit the requisite gas into the mains.

The gas-meter by which the consumer registers his consumption, is constructed upon the following principle:—When a number of vessels of a known capacity, such as one cubic foot, are arranged round a central axis in such a manner that, without any loss of gas, one after the other shall be filled with the gas in revolving, and for this purpose are inverted in water, into which the gas enters; it follows that just as many cubic feet of gas will have passed as there are vessels that have been filled. Let there be four such vessels; now, as they each in succession fill and rise, the axis will be turned once round, thereby indicating the passage of four cubic feet of gas. In the gas-meter, a section of which is here shown, instead of four separate vessels, there is, within an outer case, *b b*, more than half filled with water, a drum, *d d*, moving round on two pivots, and divided into four compartments, *a a' a'' a'''*, by as many bent partitions, but enclosed at front and back by straight sides; the partitions are bent round, so as to form a central space *g*, and thus the gas can pass from one division into the next, and also escape into the outer case, *b b*, by slits in the rim of the drum. The gas enters at the

Fig. 21.



back of the outer case by a tube which proceeds into the central space, where it turns up at *i*, and rises a little above the level of the water. One of the pivots on which the drum works is fixed in the bend of this tube; a peg on one of the straight sides at the back is the other pivot, and carries a toothed wheel. As one partition gets filled with gas, it becomes lighter and rises, thereby causing the drum to revolve; when it rises above the level of the water, its contents pass through the slit into the outer case, and from that along a tube at the top of the case for supplying the burner. While this partition is rising, another is being brought under the water, and while the one is parting with its gas, the other is being filled, and so on. The toothed wheel turns a hand, by an arrangement of wheels, upon a dial plate, a division on one plate representing one revolution of the drum, a division on the second dial representing ten, and that on the third one hundred revolutions; by which means the quantity of gas passed through the meter is measured in cubic feet.

There are some objections to this meter, such as the liability of the water to freeze in cold weather, whereby the passage of the gas is completely stopped. If the water level be lowered, so that the same compartment may communicate at once with the central and outer spaces, *g* and *b b*, more gas will pass than can be registered; or if the meter be tilted forward, the gas will pass without being registered at all. By this means the company is liable to fraud by dishonest persons. Other meters have been introduced which have not these objections; such as the *dry gas-meter*, in which the measuring chambers are separated from each other by flexible partitions of leather; but our space will not admit of further details on this subject.

The profitable consumption of gas, whereby the greatest quantity of light is obtained at the least expenditure of gas, depends in great measure upon the form of the burner, and the mode by which the flame is supplied with air necessary for its combustion.

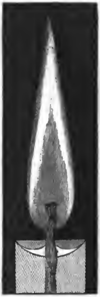
But to satisfy the conditions requisite to the production of a brilliant flame, it is necessary to understand the chemical changes which take place, in order that by our arrangements we do not interfere with the conditions or the order of the phenomena.

Flame has been defined as "a luminous bubble of gaseous matter." It is not, however, necessarily very luminous; for the flame of pure hydrogen gives little or no light, although its heat is very great. If, however, we project into this scarcely luminous flame, solid matter in a state of minute division, and not vaporizable by a very intense heat, such as charcoal dust, steel filings, magnesia, oxide of zinc, &c., these solid particles becoming white hot in falling through the flame, impart to it a high degree of luminosity. In the flames of our lamps, candles, and gas, the hydrogen supplies the heat, and the carbon the light, as will presently be seen. Let us examine the flame of a candle. In a candle we have a simple but ingenious contrivance for supplying the flame with as much melted fat as can be consumed without smoking. To effect this object, the size of the wick must bear a certain relation to the quantity of tallow or thickness of the candle. If the wick be too large, a quantity of the melted tallow will flow down the candle and be lost; if too small, the tallow will form into a thin ring-shaped wall interfering with the light; and, becoming gradually undermined, the melted tallow will gutter down, and also be lost.* But, supposing the thickness of the candle to be properly adjusted to the size of the wick, the tallow immediately below the flame is melted into the form of a hollow cup, which forms a reservoir always properly filled for feeding the flame. The fibres of the twisted cotton act as a number of capillary tubes whereby the fat is carried up into the flame, and being exposed to a high temperature, while it is at the same time sheltered from air, it undergoes a dry distillation. The inflammable vapour thus produced rises, and by constant combustion, decreases in quantity, and consequently diminishes in diameter, until at length it entirely disappears,—hence the conical shape of the flame.

---

* In *night lights* of stearine or wax there is a small wick and a great thickness of wax, whereby a deep and full reservoir is formed; this excess of melted wax causes the small light, and is prevented from escaping by the paper mould which surrounds it. It is made short, and for safety put into a saucer containing water.

FIG. 22.



Now in this, as in all common flames, perfect combustion takes place only where the air is in contact with the flame at the exterior. The air, streaming from below upwards, decomposes the inflammable vapour into hydrogen and carbon. The hydrogen burns* and forms the flame, giving heat, but no light; the carbon, at the moment it is set free, becomes white hot and imparts luminosity to the flame, but does not burn entirely, until it reaches the exterior of the flame, where the oxygen of the air seizes hold of it, and both together form carbonic acid.

On carefully examining the flame of a candle, it will be seen to consist of four portions tolerably distinct:—1. the dark interior, containing unburnt combustible vapour; 2. around this, the brilliant part of the flame, or the flame strictly so called, where the hydrogen is united with the oxygen of the air, and the carbon not having yet done so, is in the form of incandescent soot; 3. beyond this, another casing, or shell, where the oxygen of the air unites with the carbon, hardly visible in a gas flame, but readily seen in a tallow candle — especially if the end of a thread dipped in brine and dried, be then dipped into the cup of the candle, and brought within one-twentieth of an inch of the bright flame without touching it; this will render the outer flame more luminous than usual, and of a yellow colour, due to the presence of the salt; 4. the blue portion at the bottom of the flame, where the inflammable vapour undergoes perfect combustion, and no solid carbon is deposited to afford light. These are all the parts that should properly appear; but when the carbon is excessive, and either escapes or *almost* escapes unburnt at the top of the flame, its cooling below a white heat gives rise to a fifth phenomenon, in the shape of a slender cone of a deep red colour, and the light is much diminished.

---

* Or, in other words, unites with the oxygen of the air and forms water.

Thus it will be seen that the combustion of the hydrogen and some of the carbon gives the requisite heat, and the particles of the remaining carbon radiate the light. The hottest part of the flame is just at the top of the luminous cone, where combustion is perfect, but the air not sufficiently in excess to carry away the heat quickly as at the sides or in the blue part at the bottom.

The fibres of the cotton within the flame are charred, but not consumed, on account of the absence of air. If means are not taken to shorten this portion of the wick, it projects in time beyond the flame, and, coming in contact with the air, is consumed: the soot collects as a spongy mass at the top, darkening the flame, and at length falling into the cup, interferes with the proper action of the light. In wax, stearine, and sperm candles this evil is avoided by plaiting the wick, or twisting it very much, whereby the end is caused to bend considerably, and is thus brought out of the flame* and consumed; a plan which could not be adopted with tallow on account of the guttering. Tallow candles, therefore, require the use of snuffers.

---

* In Palmer's candles, by a particular twist in both wick-halves,

The inflammable vapour which forms the flame of our candles does not greatly differ in chemical composition from the carburetted hydrogen of the gas-works, and the conditions requisite to make them both burn well are pretty much the same. When the combustion of the carbon is incomplete the flame becomes smoky, and much light is lost; an effect which may be produced by holding any cold substance in or near the flame, such as a piece of cold iron; the carbon will be deposited on the metal in the form of solid soot, and the flame will be dim. In ordinary practice, however, this effect arises from the gas being in too great a proportion for the air which supports the combustion; and the obvious remedy is either to diminish the supply of gas or increase the supply of air. This may be done by modifying the form of the gas-burner or of its glass chimney. And, first, with respect to the form of the burner:—It has been found by experience that a plain jet, a quarter of an inch in diameter at the orifice, will not give a flame free from smoke of a greater height than two-and-a-half inches; but the same quantity of gas which would give a smoky flame from a plain jet will burn with a clear bright flame by extending or dividing the aperture of the jet so as to expose a larger surface of flame to the air. It is not, however, necessary actually to increase the size or superficial area of the flame; it may even be diminished with increased luminous effect either by having two small apertures instead of one large one, but making them follow an oblique direction so that the jets may cross each other; this forms the *fish-tail* flame, or by having three apertures, as in the

and by winding a thin wire round each half, they are made to fall asunder like a fork, when both ends constantly protruding through the flame are consumed.

cock's-spur. Or the light may be still further improved by making a number of small apertures so near that all the jets unite laterally into one, as in the *union jet.* Or, instead of these methods of improving on the single round jet, there may be a slit across the top of the beak so as to give a sheet of flame, as in the *bat-wing* jet, *swallow-tail,* and *fan* jets. In the Argand burner a circle of small holes of equal size supplies the gas, and a current of air is admitted through the centre of the flame.* With such an arrangement there is more combustion and consequently a higher temperature than in the plain jet; but with the same consumption of gas the Argand burner does not give so much light as the flat flames of the fish-tail and bat-wing burners; because, as luminous flame is opaque, the interior surface of the Argand flame diffuses no light sideways, but only above and below; and with small Argand burners the light thus afforded is very trifling. An Argand burner which consumes one-and-a-half cubic feet of gas per hour affords light equal to that of one candle; an Argand consuming two cubic feet per hour is equal to four candles; and when the consumption is three cubic feet per hour it is equal to ten candles.

The construction of the chimney has an important influence on the proportion of air brought into contact with the surface of the flame. Every one must have noticed that an unsteady smoky flame immediately becomes converted into a bright brilliant one as soon as the chimney is put on; for by this means the quantity of air or draught is increased. But the form and dimensions of the chimney require attention: a wide short cylindrical chimney hardly increases or diminishes the proportion of air; its advantage is to steady the flame; but if the chimney be moderately tall and narrow, or contracted towards the top, or suddenly contracted near the bottom, the draught is greatly increased and the light improved. It must not be forgotten that the supply of air to the flame may be too abundant, so that instead of assisting combustion, it may, by cooling the flame, interfere therewith. Such is often the case with the cylindrical chimney. This was remedied soon after the original invention of the Argand burner and chimney by Ami Argand in 1789, by contracting the diameter of the glass chimney at a certain height above the burner, forming a shoulder a few lines in width. The draught, as it enters the cylinder, has its direction changed at the shoulder, and is thus thrown upon the flame at a certain angle. By this contrivance, the supply of air is diminished, but it acts in a more advantageous direction, and instead of cooling the flame, assists the combustion, and increases the illuminating power. At the present time, the best form of chimney is occupying considerable attention.

---

* In the original Bude-light, proposed by Gurney, oxygen gas was passed through the flame instead of air, thereby greatly improving the brilliancy of the flame. The present Bude-light is a gas flame with two, three, or more concentric burners, with chimneys supplied with common air, and accompanied by a reflecting apparatus of peculiar construction.

In the use of gas-lights within doors some provision ought to be made for ventilation. One part by weight of well-made coal-gas produces nearly three parts by weight, or about its own bulk, of carbonic acid gas, which in large quantities is fatal to animal life, and in crowded rooms and assemblies, where ventilation is not attended to, produces head-ache, fainting, and other distressing sensations. But in addition to carbonic acid, sulphurous acid is one of the results of the combustion of gas, owing to the presence of certain sulphurous compounds which the purification of the gas does not wholly remove. This sulphurous acid, in contact with the air, becomes converted into sulphuric acid, a corrosive liquid, which attacks walls and furniture, books, &c.

To get rid of these noxious vapours, there is sometimes suspended above the chimney a bell-shaped vessel, from the upper part of which proceeds a narrow tube leading out of the apartment. By this means the vapours are carried away more or less perfectly; but if the tube be of great length the contents get cold, and cease to be carried off, so that the ventilation stops and the vapours get diffused over the room. The water produced by the hydrogen even condenses, and running back down the tube, extinguishes the flame. By an improvement of Dr. Faraday the bell-vessel is rejected, and a copper tube of about the same diameter as that of the flame conducted from its summit out of the apartment; this tube becoming heated, a rapid current is established, and the products of combustion effectually carried away.

By another contrivance of the same distinguished philosopher, the ventilating current is made to descend between two concentric glass chimneys of unequal height, the lower one being the interior; and when the current has reached the bottom, it passes through a ventilating tube bending upwards. The descending current is established by applying heat to the bend of the ventilating tube where it begins to ascend, and when this current is fully established the gas is lighted, and the exterior or higher of the two chimneys covered with a plate of mica. The Argand burner is supplied with air in the ordinary way, and the products of combustion are carried from the top of the inner chimney down through the space between that and the exterior chimney into a box, in which terminates the ventilating pipe for conveying the vapours outside. A globe of ground glass, open only at bottom, placed over the lamp, has an elegant appearance. It is said, that, notwithstanding the two glass chimneys, a greater amount of light is obtained by this arrangement, and certainly a larger flame, than with the ordinary Argand burner.

In conclusion, the writer has to express his acknowledgments to Mr. Evans, the superintendent, and to Mr. Gore, the deputy-superintendent of the Westminster Gas Works, for the attention they have given to him during several visits to this noble establishment. Under the scientific direction of these gentlemen, the various processes are conducted, and the results attained, with the utmost precision. A record is kept of the results of every operation; such as the amount of gas furnished by a given weight of coal; the temperature at which the gas enters and leaves the condenser; the temperature at which it is distributed to the public; the pressure of the gas as it enters or leaves the purifiers, the gasometers, &c. The necessity for registering these minute details every hour of the twenty-four suggested to Mr. Evans the practicability of keeping a horary meteorological register, which has now been in progress some years. Every hour of the twenty-four an observation is registered of the barometer and of the thermometer, the dry and wet bulb thermometers in the open air, the direction of the wind, the state of the weather, and the quantity of rain. The site of the Westminster Gas Works is not a good one for meteorological observations, situated as it is in a crowded neighbourhood, and being also within a few miles of the meteorological observatories of Greenwich and of Kew; but the effort is altogether so praiseworthy that the writer cannot but hope that the superintendents of provincial gas works, where these objections do not apply, will be induced to follow this example. Simultaneous horary observations carried on in distant parts of the United Kingdom would in a few years furnish the infant science of meteorology with invaluable data for the evolution of the laws which regulate the weather.

C05707173

Digitized by Google

LONDON:
R. CLAY, PRINTER, BREAD STREET HILL.

Digitized by Google

Society

FOR

Promoting Christian Knowledge.

BOOKS SUITABLE FOR PRESENTS.

Most of these Works may be had in ornamental bindings, with gilt edges, at an extra charge of 6d. each.

	Price. *s.*	 *d.*
AFRICAN KINGDOMS and PEOPLE, Sketches of the, with Map	4	0
ALICE GRAY; or, the Ministrations of a Child	2	0
AMY'S TRIALS; or, a Character Misunderstood	2	0
ASSYRIA. By P. H. Gosse, F.R.S.	8	0
BIBLE PICTURES and STORIES. With Colored Plates:—		
Old Testament. Nos. 1 to 6	0	6
New Testament. Nos. 1 to 6	0	6
In two Vols. *each*	3	0
BIRDS of the SEA-SHORE. 12 Colored Plates	1	8
BRITISH SETTLEMENTS in INDIA, History of	4	0
BRITISH FISHES, A Familiar History of. Fcap. 8vo. (*Demy* 12*mo.*)	4	0

BOOKS SUITABLE FOR PRESENTS.

	Price.	
	s.	*d.*
BRITISH BUTTERFLIES. Colored Plates	1	8
BROKEN ARM, The	2	6
CHANNEL ISLANDS, Rambles among the	3	0
CHAPTERS on COMMON THINGS by the SEASIDE. By ANNE PRATT	4	0
CHEMISTRY of CREATION	5	0
DEWDROP AND THE MIST: an Account of the Phenomena and Properties of Atmospheric Vapour in various Parts of the World. By CHARLES TOMLINSON, Esq.	3	6
ELDAD the PILGRIM	3	0
EVENINGS at the MICROSCOPE. By P. H. GOSSE, F.R.S.	8	0
FIRESIDE TALES. First and Second Series . . . *each*	1	8
FLOWERS of the FIELD. By the Rev. C. A. JOHNS	7	0
FOREST TREES, 2 Vols. By Ditto	7	6
GARDENING for CHILDREN. By Ditto	2	0
HANNAH LAVENDER; or, Ladyhall	1	8
HISTORY OF ENGLAND, for Young Persons	2	0
ILLUSTRATIONS of USEFUL ARTS, MANUFACTURES and TRADES. By CHARLES TOMLINSON, Esq. 1300 Woodcuts. In one Volume. 4to.	8	0
LAME BOY, The, and his Friends	1	0
LIFE of NELSON	2	6
LIFE of WELLINGTON	2	0
MARGARET ARNOLD. A Tale	2	0
MARY GROVE	2	6
MONTHLY FLOWER GARDEN, The. Edited by the Rev. C. A. JOHNS. 12 Colored Plates	1	8
MONTHLY GLEANINGS from the FIELD and GARDEN. Edited by Ditto. 24 Colored Plates	3	6

Digitized by Google

BOOKS SUITABLE FOR PRESENTS.

	Price.	
	s.	d.
MONTHLY WILD FLOWERS. Edited by the Rev. C. A. Johns	1	8
——— WINDOW FLOWERS. Edited by Ditto	1	8
NICHOLLS' HELP to READING the BIBLE	2	6
NO LIE THRIVES. A Tale	1	8
OCEAN, The. By P. H. Gosse, F.R.S.	4	6
OLD ARM CHAIR, The. A Retrospective Panorama of Travels by Land and Sea	3	0
OUR NATIVE SONGSTERS. By Anne Pratt. 73 Colored Plates	8	0
PARIS, RAMBLES ROUND. By the Rev. C. A. Johns	3	0
PICTURE BOOKS for CHILDREN—ANIMALS. By Ditto	1	0
PICTURES and STORIES for LITTLE CHILDREN. By Isabella E. Glennie	1	0
PITCAIRN; the Island, the People, and the Pastor. By the Rev. T. B. Murray, M.A.	2	0
POISONOUS, NOXIOUS, and SUSPECTED PLANTS. By Anne Pratt. 44 Colored Plates	6	0
ROBINSON CRUSOE	4	0
SCENES in the CAMP and FIELD; being Sketches of the War in the Crimea	2	0
SCRIPTURE MANNERS and CUSTOMS	4	0
SCRIPTURE NATURAL HISTORY	4	0
SCRIPTURE TOPOGRAPHY—PALESTINE and GENTILE WORLD *each*	6	0
SELBORNE, NATURAL HISTORY of. By the late Rev. Gilbert White, A.M. Arranged for Young Persons. A new and revised Edition	6	0

BOOKS SUITABLE FOR PRESENTS.

	Price.	
	s.	d.
SHIPWRECKS and ADVENTURES at SEA	3	0
SHORT STORIES founded on EUROPEAN HISTORY.—FRANCE, ITALY, SPAIN, SWEDEN, SWITZERLAND . . . *each*	2	0
SISTERS, The. By Mrs. TOMLINSON	3	0
SKETCHES of RURAL AFFAIRS	3	6
STORIES from ROMAN HISTORY	3	0
——— for the NURSERY	2	0
TEMPEST, The ; or, an Account of the Nature, Properties, Dangers, and Uses of Wind in various Parts of the World	2	6
TEXT BOOK of ZOOLOGY. By P. H. GOSSE, F.R.S.	3	6
THUNDER-STORM, The. By C. TOMLINSON, Esq. New Edition. Fcap. 8vo.	3	0
TWINS, The ; or, Home Scenes	1	8
TWO FIRESIDES, The. A Tale	2	0
WANDERINGS through the CONSERVATORIES at KEW GARDENS	2	6
WILD FLOWERS. By ANNE PRATT. 2 Vols. 192 Colored Plates	16	0
YEAR of COUNTRY LIFE ; or, Chronicle of the Young Naturalist	2	6

An Allowance of 25 per Cent. to Members.

DEPOSITORIES:
77, Great Queen Street, Lincoln's Inn Fields ; 4, Royal Exchange ;
16, Hanover Street, Hanover Square.

Digitized by Google

Digitized by Google

SPENCER & SON
BINDERS

Digitized by Google

Digitized by Google